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(71)Applicant : CHICHIBU ONODA CEMENT CORP

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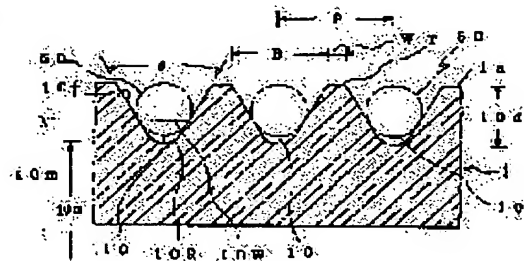
(72)Inventor : SAITO HIROSHI
SASAKI MASAO
MATSUI KATSUMI
TANAKA NOBUHISA
SAKAMOTO SHINJI

(54) CERAMICS-MADE MULTIGROOVE ROLLER FOR WIRE SAW

(57)Abstract:

PROBLEM TO BE SOLVED: To prevent generation of chipping at groove working time, by forming a groove forming part of a ceramics-made multigroove roller by ceramics of a prescribed % or more alumina content.

SOLUTION: A ceramics-made multigroove roller 1 for a wire saw is formed into a hollow cylindrical shape by ceramics. As this ceramics, an alumina content is 90% or more, for instance, ceramics of 97% purity or the like is used. In a surface 1a of the multigroove roller 1, a plurality of wire grooves 10 are provided with a space apart in a center core axial direction. Deflection in a radial direction of the wire groove 10 relating to the center core axis of the multigroove roller 1 is 20 μ m or less, deflection in an axial direction of the wire groove 10 relating to the center core axis of the multigroove roller 1 is 20 μ m or less.



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(71)出願人 00000240

秩父小野田株式会社

東京都港区西新橋二丁目14番1号

(72)発明者 斉藤 弘

山口県小野田市大字小野田6276番地 秩父
小野田株式会社セラミックス事業本部小野
田事業所内

(72)発明者 佐々木 正雄

東京都港区西新橋2-14-1 株式会社サ
イマレック内

(74)代理人 弁理士 斎藤 侑 (外2名)

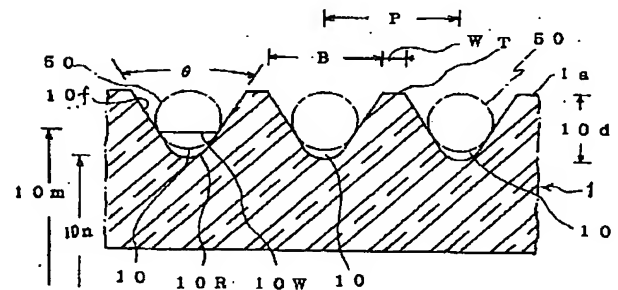
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(54)【発明の名称】 ワイヤソーのセラミックス製多溝ローラ

(57)【要約】

【課題】溝加工時にチッピングが発生しないようにするとともに、ワイヤー溝の深さを従来例のそれより浅くし、且、脱線、断線が生じないようにする。

【解決手段】表面に複数のワイヤー溝と溝間山とを有するワイヤソーのセラミックス製多溝ローラにおいて、該セラミックス製多溝ローラの溝形成部分を、アルミナ含有量が90%以上のセラミックスで形成する。



【特許請求の範囲】

【請求項 1】 表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、アルミナ含有量が 90% 以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項 2】 表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、曲げ強度 3500 kg/cm^2 以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項 3】 表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの 2 本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラのワイヤー溝の深さが、 $50 \sim 500 \mu\text{m}$ であり、該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが $20 \mu\text{m}$ 以下であり、該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが $20 \mu\text{m}$ 以下であることを、を特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項 4】 表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの 2 本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラが、アルミナの含有量が 90% 以上のセラミックスで形成され、該多溝ローラのワイヤー溝の深さが、 $50 \sim 500 \mu\text{m}$ であり、該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが $20 \mu\text{m}$ 以下であり、該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが $20 \mu\text{m}$ 以下であることを、を特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項 5】 表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの 2 本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラが、曲げ強度 3500 kg/cm^2 以上の

セラミックスで形成され、

該多溝ローラのワイヤー溝の深さが、 $50 \sim 500 \mu\text{m}$ であり、

該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが $20 \mu\text{m}$ 以下であり、

該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが $20 \mu\text{m}$ 以下であることを、

を特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項 6】 一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、 $30 \mu\text{m}$ 以下であることを特徴とする請求項 1、2、3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項 7】 一本のセラミックス製多溝ローラの溝ピッチの誤差の累積が、 $30 \mu\text{m}$ 以下であることを特徴とする請求項 1、2、3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項 8】 一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、 $30 \mu\text{m}$ 以下であり、該ワイヤー溝のピッチの誤差の累積が、 $30 \mu\text{m}$ 以下であることを特徴とする請求項 1、2、3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項 9】 被加工物に対向する 2 本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が $60 \mu\text{m}$ 以下であることを特徴とする請求項 3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項 10】 被加工物に対向する 2 本のセラミックス製多溝ローラの、相対するワイヤー溝の溝ピッチの相互累積誤差が $60 \mu\text{m}$ 以下であることを特徴とする請求項 3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項 11】 被加工物に対向する 2 本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が $60 \mu\text{m}$ 以下であり、かつ、相対する該ワイヤー溝の溝ピッチの相互累積誤差が $60 \mu\text{m}$ 以下であることを特徴とする請求項 3、4、又は、5 記載のワイヤーソーのセラミックス製多溝ローラ。

【発明の詳細な説明】

【0001】

【発明の属する技術分野】この発明は、シリコン、磁性体、水晶等を切断するワイヤーソーに関するもので、更に述べると、ワイヤーソーのセラミックス製多溝ローラに関するものである。

【0002】

【従来の技術】ワイヤーソーは、ワイヤーを張設した複数の多溝ローラを備えており、該多溝ローラを回転させて該ワイヤーを直線運動させることにより、シリコン、磁性体、水晶、セラミックス等の被加工物（ワーク）を切断する。

【0003】従来の多溝ローラは、樹脂例えばナイロンで形成され、その表面には複数のワイヤー溝が設けられている。このワイヤー溝の深さは、通常0.5～1mmの範囲で形成されるが、その材質が柔軟であり、かつ、加工性も良いので、ワイヤー溝の加工作業が容易である反面、磨耗し易いので耐久性において問題がある。そこで、近年、前記問題を解決するため、セラミックス製ローラが使用されている（特開昭63-237863号公報参照）。

【0004】

【発明が解決しようとする課題】セラミックスの硬度は、ナイロンに比べ著しく高く、例えば、66ナイロンのロックウェル硬度は、R112であるが、アルミナの含有量が97%のセラミックスはその硬度が高過ぎるので、ロックウェル硬度での測定は不可能である。そこで、該セラミックスのピッカース硬度を測定したところ、Hv1400であった。このHv1400は高過ぎでロックウェル硬度との比較はできない。

【0005】多溝ローラのワイヤー溝がナイロンで形成されている場合は、ワイヤー溝の精度誤差をワイヤー溝が変形若しくは、ワイヤーが伸縮して補っていた。しかし、該ワイヤー溝がセラミックスで形成されている場合、ワイヤー溝が変形しないため、ワイヤー溝の精度誤差のすべてをワイヤーが伸縮することのみによって補わなければならない。従って、ワイヤー溝がセラミックスで形成される場合、ワイヤーにかかるストレスがナイロンでワイヤー溝を形成された場合よりはるかに多い。

【0006】上記事情より、ワイヤーソーのセラミックス製多溝ローラは、ナイロン製多溝ローラよりはるかに高い精度でワイヤー溝を形成しなければならない。

【0007】ナイロン製多溝ローラは、NC旋盤を用いたバイトによる切削によりワイヤー溝を加工していた。しかし、セラミックス製ローラのワイヤー溝を加工する場合は、前述の様にセラミックスは極めて硬度が高い為、例えばNC円筒研削盤を用いたダイヤモンド砥石による研削加工になる。そのため、従来例に比べ加工に要する時間が著しく長くなるとともに、加工費用も嵩むようになる。

【0008】その上、砥石先端の磨耗が激しく、一本のセラミックス製多溝ローラの溝加工の途中で砥石を交換しなければならないことがある。しかし、該砥石を交換すると、ワイヤー溝と該砥石との位置関係を交換直前の状態に精確に合わせることが困難であり、結果ワイヤー溝の溝ピッチの誤差要因となる。そのため、ワイヤー溝を設計通りに精確に形成することができず、脱線や、断線の原因となることがある。

【0009】そこで、ワイヤー溝の深さを従来のナイロン製多溝ローラより浅くすることにより、前記問題を解決することが考えられる。しかし、ワイヤー溝を浅くするとワイヤーの脱線が発生し易くなり、ワイヤーが脱線

してしまうと切断中の被加工物（ワーク）を駄目にしてしまう。

【0010】又、前述の様にセラミックス製多溝ローラは変形がほとんど無いので、加工精度向上及び加工速度向上の為、ナイロン製多溝ローラよりワイヤーに高い張力を掛けて使用されることが多い。更に、この多溝ローラは被加工物（ワーク）の削り量を減らす為、及び一度に多くの数量を切断する為に、細い径のワイヤー、例えば、直径0.1mmのピアノ線が使用される。そのため、ワイヤーに設計値よりわずかでも多い荷重がワイヤーにかかる断線してしまう。

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【0011】更に、近年では被加工物（ワーク）の多様化が進み、それに伴い要求されるワイヤー溝の溝ピッチも多種にわたってきている。特に、被加工物を極薄肉に加工する場合には、溝ピッチ0.2mm以下が要求されるが、この溝ピッチが小さくなると、それに比例して、溝間山の山頂山幅も当然小さくなる。しかし、セラミックス製多溝ローラは硬脆性材料であるため、山頂山幅を小さくすればワイヤー溝加工時に溝間山にチッピングが発生する。そのため、溝間山を設計通りに形成することが困難となる。溝間山が設計通りに形成出来ない場合には、ワイヤーの脱線、断線が発生したり被加工物（ワーク）の加工精度にも悪影響を及ぼす。

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【0012】この発明は、上記事情に鑑み、溝加工時にチッピングが発生しないようにすることである。他の目的は、ワイヤー溝の深さを従来例のそれより浅くするとともに、脱線、断線が生じないようにすることを目的とする。

【0013】

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【課題を解決するための手段】この発明は、表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、アルミナの含有量が90%以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ、である。この発明は、表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、曲げ強度3500kg/cm²以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ、ある。

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【0014】この発明は、表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの2本以上がセラミックス製多溝ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラのワイヤー溝の深さが、50～500μmであり、該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが20μm以下

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であり、該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが $20\mu\text{m}$ 以下であること、を特徴とするワイヤーソーのセラミックス製多溝ローラ、である。この発明において、一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、 $30\mu\text{m}$ 以下であり、該ワイヤー溝のピッチの誤差の累積が $30\mu\text{m}$ 以下であるように形成したり、又、被加工物に対向する2本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が $60\mu\text{m}$ 以下であり、該ワイヤー溝の相対する溝ピッチの相互累積誤差が $60\mu\text{m}$ 以下であるように形成してもよい。

【0015】

【発明の実施の形態】本発明者は、溝間山の山頂山幅を狭く、例えば、 $40\mu\text{m}$ 以下にすると、チップングが発生するのは、材質に問題があるのではないかと考え、アルミナ成分の含有量を変えながらチップングが発生するか否かを実験した。その結果、アルミナの含有量が90%以上、又は、曲げ強度が $3500\text{kg}/\text{cm}^2$ 以上になると、溝間山の山頂山幅が狭くなっても、例えば、 $40\mu\text{m}$ となってもチップングが発生しないことがわかった。そこで、セラミックス製多溝ローラの材質としてアルミナの含有量が90%以上のセラミックス又は曲げ強度 $3500\text{kg}/\text{cm}^2$ 以上のセラミックスを採用することとした。

【0016】本発明者は、セラミックス製多溝ローラの場合にワイヤーが脱線したり、断線したりし易いのは、ワイヤー溝がナイロン製多溝ローラに比べ、変形量が極く少ないためであると考えた。即ち、ナイロン製多溝ローラでは、ワイヤー溝が変形若しくは、ワイヤーが伸張することによって多溝ローラのワイヤー溝の振れ等の精度を補っているが、セラミックス製多溝ローラでは、ワイヤー溝の変形による調整はほとんど無く、ワイヤーのみですべての精度を補っているのである。

【0017】ワイヤーの脱線、断線を防止するには、設計値に対して誤差が無い様に精確にワイヤー溝を形成すれば良いが、そのように形成することは、極めて困難である。そこで、本発明者は、脱線、断線の原因を追求したところ、その主なる原因は、多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れ（以下アキシャル方向の振れ、という）と多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れ（以下ラジアル方向の振れ、という）にあることがわかった。

【0018】そこで、これらの振れが生じて脱線、断線しない範囲、即ち、振れの許容範囲を求めたところ、ワイヤー溝の深さが、 $50\sim 500\mu\text{m}$ のセラミックス製多溝ローラのワイヤー溝では、アキシャル方向の振れが $20\mu\text{m}$ 以下、ラジアル方向の振れが $20\mu\text{m}$ 以下、であることがわかった。

【0019】更に次の条件を満たすと、より好ましいことがわかった。

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(1) 一本の多溝ローラのワイヤー溝の径、即ち、ワイヤー溝の溝底の径及びワイヤーがワイヤー溝の両側壁に当接する点を結ぶ直線部の径、のばらつきが $30\mu\text{m}$ 以下であること。

(2) 被加工物に対向する2本のセラミックス製多溝ローラの、該各多溝ローラのワイヤー溝の直径、即ち、ワイヤー溝の溝底の径及びワイヤーがワイヤー溝の両側壁に当接する点を結ぶ直線部の径、のばらつきの合計が $60\mu\text{m}$ 以下であること。

10 【0020】(3) 一本の多溝ローラのワイヤー溝の溝ピッチ累積誤差が $30\mu\text{m}$ 以下であること。

(4) 被加工物に対向する2本のセラミックス製多溝ローラの相対するワイヤー溝の溝ピッチの累積誤差が $60\mu\text{m}$ 以下であること。そこで、以上の許容範囲内のワイヤー溝を加工条件として採用することにした。

20 【0021】なお、セラミックス製多溝ローラのワイヤー溝はワイヤーが嵌着出来る様に形成されなければならないが、その形状、大きさ、数等は必要に応じて適宜選択される。例えば、ワイヤーがワイヤー溝の溝底に当接する様な形状にしたり、又、ワイヤーがワイヤー溝の両側壁に当接する様な形状等、に形成される。

【0022】又、多溝ローラを形成するセラミックスとして、純度90%以上、即ちアルミナの含有量が90%以上のセラミックス、ジルコニア、炭化珪素、窒化珪素等が用いられる。

【0023】

【実施例1】この発明の第一実施例を図1～図6により説明する。ワイヤーソーのセラミックス製多溝ローラ1はセラミックスにより中空円筒状に形成されており、その外径Dは、 40mm 、内径1dは 20mm 、長さLnは 100mm 、である。このセラミックスとして、アルミナの含有量が90%以上、例えば、純度97%のセラミックス等が用いられる。

【0024】該多溝ローラ1の中空部2には、補強部材5が設けられている。この補強部材5は、該多溝ローラ1と一体に形成された同芯状の円盤形状である。この円盤形状の補強部材5の厚さ5tは、多溝ローラ1の肉厚 $1t=10\text{mm}$ と同一厚さ、であり、両者の肉厚比 $1t/5t$ は1であるが、この肉厚比 $1t/5t$ は多溝ローラの剛性等を考慮して選択される。

【0025】円盤形状の補強部材5は、1個設けられているが、この配設個数も該多溝ローラ1の長さLn等を考慮し、適宜選択され、例えば、中芯軸C方向に等間隔に3つの円盤形状の補強部材5が配設される場合や、逆に補強部材5を省略することもある。

【0026】円盤形状の補強部材5には、5個の軽量化用穴6が設けられており、この軽量化用穴6により補強部材5の軽量化を図る。この軽量化用穴6の位置、個数、形状等は、要求される多溝ローラ1の剛性等を考慮して適宜選択され、例えば、軽量化用穴6が貫通してい

なかったり、8個の多角形状の軽量化用穴6が採用されたりする。

【0027】該多溝ローラの表面1aには、中芯軸C方向に間隔をおいて複数のワイヤー溝10が設けられている。このワイヤー溝10は、図示しないNC円筒研削盤により設計図に基づいて精確に加工される。例えば、そのワイヤー溝深さ10d=0.12mm、溝角度 $\theta=60^\circ$ 、溝ピッチP=0.24mm、溝幅=0.2mm、溝間山の山頂山幅W=0.04mm、溝数296、に形成される。

【0028】該多溝ローラ1の両端1eには円盤状に形成された金属製支持部材30が設けられている。該金属製支持部材30の外面30aの中央部には、軸部31が配設され、又、その内面30bの外周部には、嵌合部33が形成されている。この嵌合部33は多溝ローラ1の端部1eに嵌合されているが、該両部33、1eはエポキシ樹脂等の接着剤35により接着されている。

【0029】この両部33、1eの接合長さL33は多溝ローラ1の長さLnより極めて短いので、ワイヤーソーの装置を運転することにより温度変化が生じ両者が伸縮して変位しても両部の接合状態は維持される。尚、この金属製支持部材30は、一般に鉄、鋼などが用いられるが、セラミックスの熱膨張率と同一又は近似な熱膨張率の材料で円盤形状に形成されるのが好ましく、例えば、この材料として、チタンやチタン合金等が用いられる。

【0030】次にワイヤーソーの作動について説明する。図示しないワイヤーソーの多溝ローラ取付部位に多溝ローラ1の軸部31を装着する。この装着された複数の多溝ローラ1を囲む様にしながら一本の直径0.12mmのワイヤー50を相対するワイヤー溝10に巻き付け、多数のワイヤー列50Aを形成する。この時、一本の多溝ローラのワイヤー溝の直径、即ち、ワイヤー溝底10Rの直径10n、ワイヤー溝の両側の側壁10fとワイヤーとが接触する当接点を結ぶ直線部10Wの直径10mのばらつきが $30\mu\text{m}$ 以下であり、該ワイヤー溝の溝ピッチPの累積誤差が $30\mu\text{m}$ 以下、である。

【0031】又、一装置内で使用されている被加工物に対向する2本のセラミックス製多溝ローラの各々の多溝ローラのワイヤー溝の直径のばらつきの合計、即ち、各セラミックス製多溝ローラのワイヤー溝底10Rの直径10n、ワイヤー溝の両側の側壁10fとワイヤーとが接触する当接点を結ぶ直線部10Wの直径10mのばらつきの合計が $60\mu\text{m}$ 以下であり、相対するセラミックス製多溝ローラの相対する溝ピッチPの相互誤差の累積が $60\mu\text{m}$ 以下である。

【0032】多溝ローラを反転往復、若しくは一方向回転運動することによりワイヤー列50Aを矢印A50の様に往復若しくは、一方向直線運動させる。この時のセラミックス製多溝ローラ1の中芯軸Cに対するワイヤー

溝10のラジアル方向ARの振れは $20\mu\text{m}$ 以下であり、又、該セラミックス製多溝ローラ1の中芯軸Cに対するワイヤー溝10のアキシャル方向AXの振れが $20\mu\text{m}$ 以下、である。

【0033】このワイヤー50に被加工物(ワーク)BWを押し当てるとともに、図示しない吐出ノズルから研磨材を吐出し、両者間に研磨剤を介在せしめながら切断を行う。

【0034】このセラミックス製多溝ローラ1の回転に伴い、慣性力が発生するが、この多溝ローラ1は、従来例に比べ極めて軽量なので、その慣性力も極めて小さいものになる。

【0035】又、ワイヤーソーの運転時において、温度変化が生じ、該セラミックス製多溝ローラ1と金属製支持部材30とが共に伸縮することがあるが、両者1、30を熱膨張率が略等しい材料にすると、略同一割合で同時に伸縮する為、接着部位の剥離等が発生しないので、好ましい。

【0036】上記ワイヤーソーの運転時においてワイヤー溝の振れが発生するが、該多溝ローラ1の中芯軸Cに対するワイヤー溝10のラジアル方向ARの振れは $20\mu\text{m}$ 以下であり、又、該多溝ローラ1の中芯軸Cに対するワイヤー溝10のアキシャル方向AXの振れが $20\mu\text{m}$ 以下である。

【0037】上記セラミックス製多溝ローラを使用したワイヤーソーで直径が8インチのシリコンの切断加工を行った結果、ワイヤーの脱線、断線等が発生せず、又セラミックス部と金属製支持部材の剥離等もみられず、被加工物であるウエハーの寸法精度は $5\mu\text{m}$ 以上を維持して加工することができた。

【0038】本実施例におけるセラミックス製多溝ローラ1の中芯軸Cに対するラジアル方向ARのワイヤー溝の振れの許容範囲は、計算によっても求められる。この振れの許容範囲は、脱線が発生する振れの限界を示すものである。

【0039】次に、本実施例の脱線計算図である図6により前記許容範囲を計算する。ワイヤーソーのワイヤーの脱線は様々な原因が合わさって発生するが、その脱線の経過は次の通りである。

(1) 隣のワイヤー溝から走行してきたワイヤーはワイヤー溝に対して斜めに入ってくるため、図6のB付近の様に該ワイヤー溝の側壁10fにワイヤー50が接触する。

【0040】(2) 該ワイヤーはセラミックス製多溝ローラ1の回転及び側壁10fの外周方向への力を受ける。

(3) セラミックス製多溝ローラのワイヤー溝のラジアル方向ARの振れにより二本の対向する多溝ローラ間の中芯軸C間隔Lが短くなり、ワイヤー50が緩んで脱線する。

【0041】この脱線時を示す図6から次の関係式が求められる。

$$y+z=L+l+\Delta x \quad (1)$$

$$\cos \theta = r / (r+t) \quad (2)$$

$$l=2\pi r \times \theta / 360 \quad (3)$$

$$r^2+z^2=(r+t)^2 \quad (4)$$

$$(L-\Delta x)^2+t^2=y^2 \quad (5)$$

【0042】上記式において、L：多溝ローラ間の理論的に精確な距離、l：円弧の長さ、r：多溝ローラとワイヤーの接触部分の半径、t：脱線開始時のワイヤー移動距離、 Δx ：多溝ローラのワイヤー溝の振れ量、をそ*

$$(2) \text{ 式より } \cos \theta = 20 / (20+0.4) = 0.98039 \\ \theta = \cos^{-1} 0.98039 = 11.365^\circ$$

$$(3) \text{ 式より } l = 2\pi \times 20 \times 11.365 / 360 = 3.9671$$

$$(4) \text{ 式より } z = \sqrt{(r+t)^2 - r^2} \\ = \sqrt{(20+0.4)^2 - 20^2} \\ = 4.0200$$

【0045】(1)、(5)式より

$$(L-\Delta x)^2+t^2=(L+l+\Delta x-z)^2 \\ \therefore (100-\Delta x)^2+0.4^2 \\ = (100+3.967-4.0200+\Delta x)^2 \\ 10000-200\Delta x+\Delta x^2+0.16 \\ = 9989.4028+199.894\Delta x+2\Delta x^2 \\ \therefore \Delta x^2+399.894\Delta x-10.757=0 \\ \Delta x=26.9[\mu m]$$

【0046】計算例2：脱線が発生する多溝ローラのワイヤー溝の振れ量 Δx を求めるための条件。

$$L=100 \quad \text{単位} [\text{mm}]$$

$$r=30$$

$$t=0.4$$

計算例1と同様に計算して

$$\Delta x=21.7[\mu m]$$

【0047】上記計算例によりセラミックス製多溝ローラのワイヤー溝の振れ量 Δx を求めたが、セラミックス製多溝ローラの中芯軸Cに対するワイヤー溝のラジアル方向ARの振れは、前記計算例1、2より20 μm 以下になる様に製作することが望ましい。

【0048】

【実施例2】この発明の第2実施例を図7により説明する。この実施例と第1実施例との相違点は、次の通りである。ワイヤー溝10の断面形状において、底面の溝角度 $\theta_1=90^\circ$ 、側壁の溝角度 $\theta_2=10^\circ$ 、溝幅B=0.3mm、溝間山の山頂山幅W=0.1mm、溝深さ10d=0.3mm、溝ピッチ=0.4mmであることである。

*それぞれ示す。

【0043】上記式(1)～(5)より、脱線の発生する多溝ローラのワイヤー溝の振れが求められる。次にその計算例を示す。

計算例1：脱線が発生する多溝ローラのワイヤー溝の振れ量 Δx を求めるための条件。

$$L=100 \quad \text{単位} [\text{mm}]$$

$$r=20$$

$$t=0.4$$

【0044】

【0049】

【実施例3】この発明の第3実施例を図8により説明する。セラミックス製多溝ローラのアルミナ含有量(純度%)又は曲げ強度と加工時にチップングが発生しない溝間山の山頂山幅との関係を知る為に次の実験をした。図8に示す様に、アルミナ含有量の異なるセラミックス製多溝ローラ1に同一形状のワイヤー溝10をピッチ0.4mmから1 μm づつ狭めていき該各多溝ローラにおいてチップングの発生が見られる最大山頂山幅Wを調べた。尚加工条件は次の通りである。

【0050】加工機：NC円筒研削盤

砥石：ダイヤモンド砥石、粒度#400

加工ワーク(アルミナ材)：直径65mm、長さ100mm

40 回転数200rpm

加工溝形状：溝角度 $\theta=60^\circ$ 、溝深さ10d=0.15mm

実験の結果を表1及び図9、図10に示す。

【0051】

【表1】

アルミナ純度 (%)	チップ発生最大山幅 (μm)				曲げ強度 (kg/cm^2)
	実験1	実験2	実験3	平均	
75	99	93	84	92.0	2300
88	82	72	73	75.6	2700
90	31	34	31	32.0	3500
97	44	45	32	40.3	4100
99.5	18	13	19	16.7	3600

【0052】図9はアルミナ含有量即ちアルミナ純度（横軸%）とチップ発生山頂山幅（縦軸 μm ）との関係を示す図である。この図において、丸印は第1回目の実験結果、正方形印は第2回目の実験結果、三角印は第3回目の実験結果、×印は平均を示す。

【0053】図10はアルミナ純度（横軸%）とチップ発生山頂山幅（左縦軸 μm ）と曲げ強度（右縦軸 kg/cm^2 ）との関係を示す図である。この図において正方形印は山頂山幅、丸印は曲げ強度を示す。

【0054】表1及び図9、図10から材質がアルミナ含有量75%、88%のもの又は曲げ強度2300 kg/cm^2 、2700 kg/cm^2 のものの山頂山幅は、アルミナ純度90%、92%、97%、99.5%のもの、又は、曲げ強度3500 kg/cm^2 、4100 kg/cm^2 、3600 kg/cm^2 のものの山頂山幅に比べ2、3倍以上広いことがわかった。即ち、山頂山幅Wはアルミナの含有量が90%以上又は曲げ強度3500 kg/cm^2 以上になると、極端に狭くしてもチップが発生しないことがわかった。

【0055】

【実施例4】この発明の第4実施例を説明する。純度97%のアルミナからなる直径60mmのセラミックス製多溝ローラに溝ピッチ $P=0.3\text{mm}$ 、溝間山の山頂山幅 $W=50\mu\text{m}$ のワイヤー溝をダイヤモンドホイールを用いて加工したが、チップは発生しなかった。この多溝ローラをワイヤーソーに装着し、水晶の極薄切断加工を行ったところ、厚さ精度は $5\mu\text{m}$ 以上と精密な切断が行われた。ワイヤー溝は、ワイヤーに付着した砥粒により微かづつ研磨され磨耗するが、300時間という長時間にわたり上記精度を保って切断加工を行うことができた。

【0056】

【実施例5】この発明の第5実施例を説明する。純度9

7%のアルミナからなる上記同様の仕様のセラミックス製多溝ローラにワイヤー溝ピッチ $P=0.25\text{mm}$ 、溝間山の山頂山幅 $W=40\mu\text{m}$ のワイヤー溝をダイヤモンドホイールを用いて加工したが、実施例4と同様にチップは発生しなかった。この多溝ローラをワイヤーソーに装着し磁性体の極薄切断加工を行ったところ、ワークの厚さ精度は上記同様 $5\mu\text{m}$ 以上を維持することができた。

【0057】

【実施例6】この発明の第6実施例を図11により説明する。ローラは必ずしも全部を前記セラミックスで形成する必要はなく、溝形成部分が前記セラミックスで形成されておれば足りる。その具体例は、次の通りである。

(1) 図11(A)に示す様に、金属製パイプ80に、ワイヤー溝10の付いた前記セラミックス製の円筒状外周部81を設ける。この金属パイプ80の両端には装着部82が設けられ、又、一端には外周部81を固定するための止め部材83が設けられている。

【0058】(2) 図11(B)に示す様に、金属製パイプ90にワイヤー溝10の付いた前記セラミックス製の円筒状外周部91を設ける。一端90aには、突状環部92が形成され、中空部93には、穴94のあいた補強円板95が設けられ、その他端90bには、該外周部91を固定する蓋体96が固定される。

【0059】

【実施例7】この発明の第7実施例を図12により説明する。この実施例も前記第6実施例と同様に溝形成部分が前記セラミックスで形成されて場合である。

(3) 図12(A)に示す様に、金属製パイプ100にワイヤー溝10の付いた前記セラミックス製の円筒状外周部101を設ける。この金属製パイプ100の一端2100aには、ベアリング軸部105が設けられ、他端100bには円錐台状の軸受部106が形成されてい

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る。該パイプ100の外周には円筒状凹部107が形成され、この凹部107に前記円筒状外周部101が嵌着され固定されている。

【0060】(4) 図12(B)に示す様に、金属製パイプ110に、ワイヤー溝10の付いた前記セラミックス製の円筒状外周部111を設ける。この金属製パイプ110の両端には、円錐台状の軸受部115、116が設けられている。該パイプ110の外周には、円筒状凹部117が形成され、該凹部117に前記円筒状外周部111が嵌着され固定される。

【0061】

【実施例8】この発明の第7実施例を図13により説明する。前記実施例では、溝形成部分を前記セラミックスで形成したが、このセラミックス製多溝ローラ全体を前記セラミックスで形成することもできる。その具体例は、次の通りである。

(1) 図13(A)に示す様に、前記セラミックスにより中空円筒状のローラ120を形成し、該ローラの外周部121にワイヤー溝10を形成する。このローラ120は前記第1実施例と異なり中空部123内に補強部材

がないので、強度を維持するため、その肉厚 R_t は、第1実施例のそれより厚く、例えば、2倍の厚さに形成される。

【0062】(2) 図13(B)に示す様に、前記セラミックスにより中空円筒状のローラ130を形成し、該ローラ130の外周部131にワイヤー溝10を形成する。このローラ130の一端にはベアリング軸部135が設けられ、他端には円錐台状の軸受部136が設けられている。なお、ベアリング軸部135はベアリングとのなじみを良くするために、金属138で覆われている。

【0063】

【発明の効果】この発明は次の様な顕著な効果を奏する。

(1) セラミックス製ローラが、アルミナ90%以上のセラミックスで形成されているので、ワイヤー溝間山の山頂幅を狭くしても、チッピングが発生しない。そのため、従来例に比べワイヤー溝の溝ピッチを大幅に小さくすることができる。

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【0064】(2) セラミックス製ローラが、曲げ強度 3500 kg/cm^2 以上のセラミックスで形成されているので、ワイヤー溝間山の山頂幅を狭くしても、チッピングが発生しない。そのため、従来例に比べワイヤー溝の溝ピッチを大幅に小さくすることができる。

【0065】(3) 該ワイヤー溝の深さが、 $50\sim500\mu\text{m}$ であり、該ローラの中心軸に対するワイヤー溝のラジアル方向の振れが $20\mu\text{m}$ 以下であり、該ローラの中心軸に対するワイヤー溝のアキシャル方向の振れが $20\mu\text{m}$ 以下であるので、従来例に比べワイヤー溝の深さが浅くなり、又、浅くしても脱線や断線が発生しない。そのため、ワイヤー溝の加工時間および費用が従来例に比べ著しく減少する。

【図面の簡単な説明】

【図1】本発明の第1実施例を示す縦断面図で、図4のI-I線断面図である。

【図2】図1のII-II線断面図である。

【図3】図1の拡大図の一部を示す図である。

【図4】使用状態を示す図である。

【図5】図4のV-V線断面図である。

【図6】脱線計算図を示す概念図である。

【図7】第2実施例を示す縦断面図である。

【図8】第3実施例を示す断面図の要部を示す図である。

【図9】アルミナ純度とチッピング発生山頂幅と関係を示す図である。

【図10】チッピング発生時の山頂幅を曲げ強度との関係を示す図である。

【図11】本発明の第6実施例を示す図である。

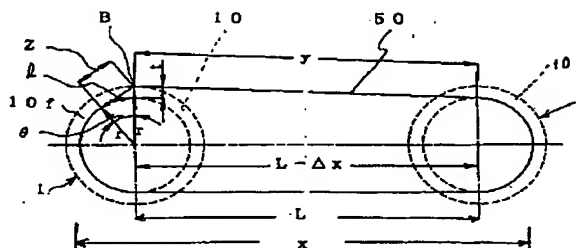
【図12】本発明の第7実施例を示す図である。

【図13】本発明の第8実施例を示す図である。

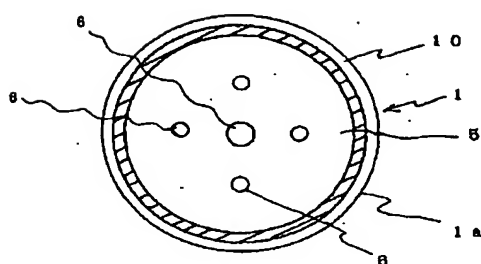
【符号の説明】

1	セラミックス製多溝ローラ
2	中空部
5	補強部材
10	ワイヤー溝
30	金属製支持部材
50	ワイヤー
AX	多溝ローラのワイヤー溝のアキシャル方向
AR	多溝ローラのワイヤー溝のラジアル方向

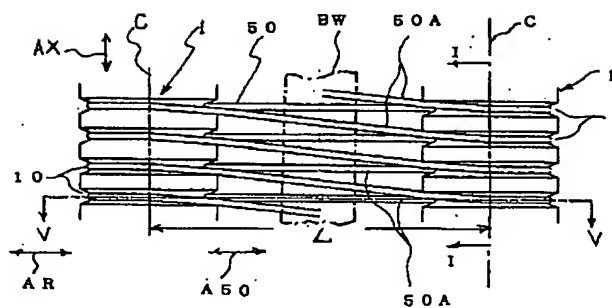
【図6】



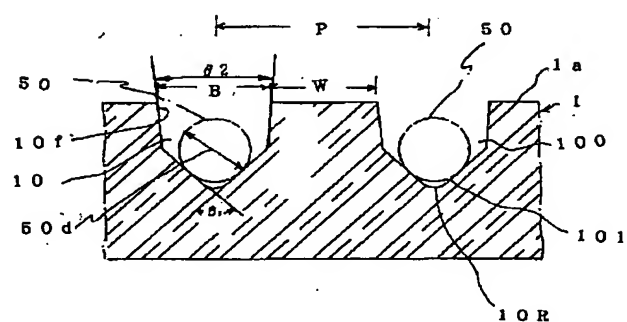
【図 2】



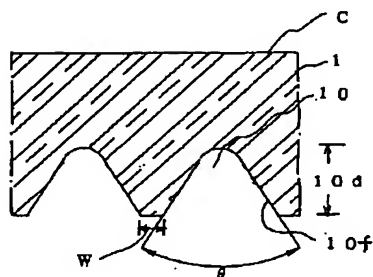
【図 4】



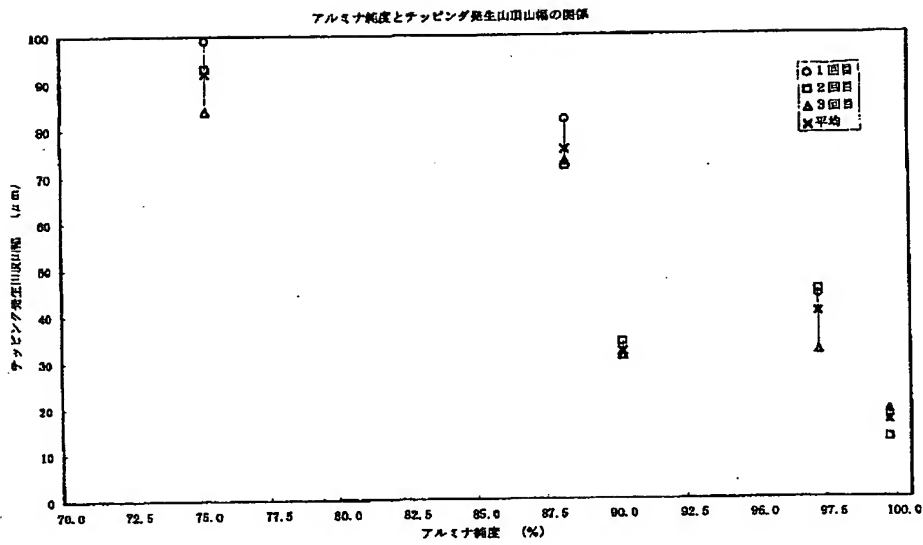
【图 7】



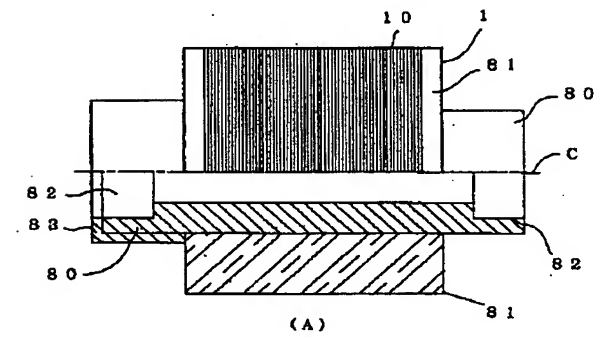
【图 8】



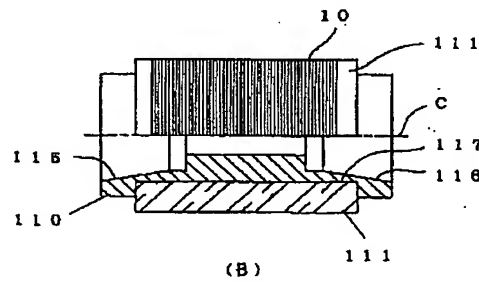
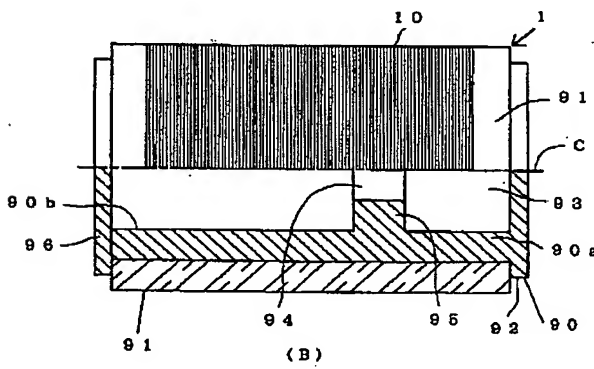
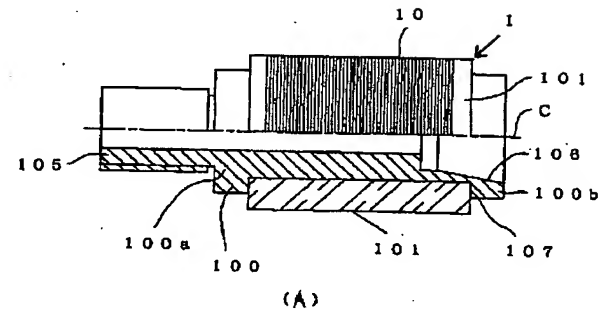
【図9】



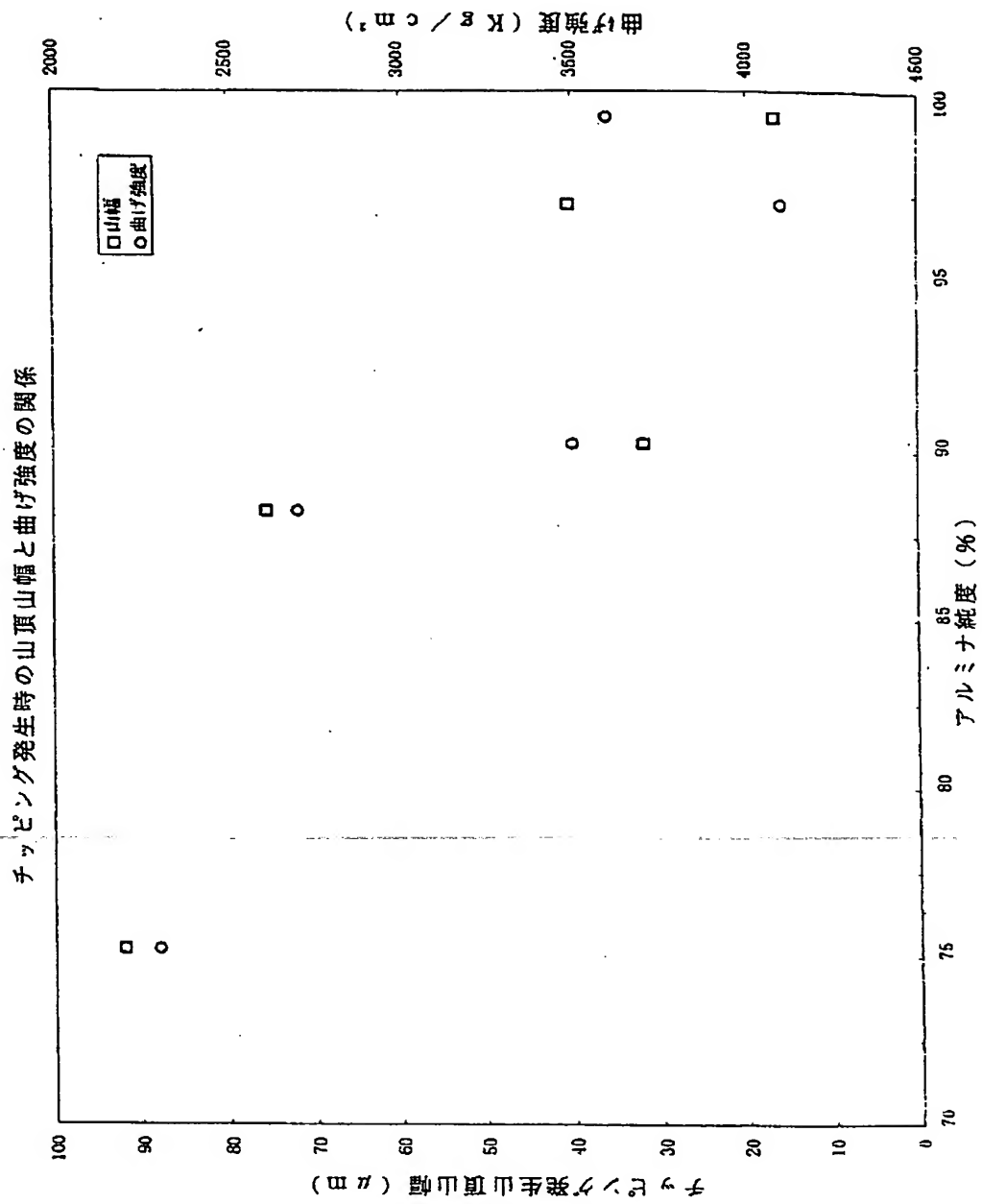
【図11】



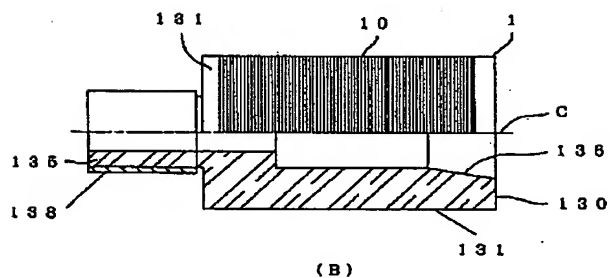
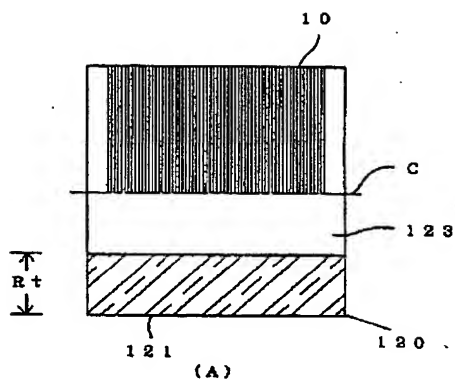
【図12】



【図10】



【図13】



フロントページの続き

(72) 発明者 松井 克己

山口県小野田市大字小野田6276番地 秩父
小野田株式会社セラミックス事業本部小野
田事業所内

(72) 発明者 田中 宜久

山口県小野田市大字小野田6276番地 秩父
小野田株式会社セラミックス事業本部小野
田事業所内

(72) 発明者 坂本 信治

山口県小野田市大字小野田6276番地 秩父
小野田株式会社セラミックス事業本部小野
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CLAIMS

[Claim(s)]

[Claim 1] The multi-slot roller made from the ceramics of the wire saw characterized by forming the alumina content for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on a front face.

[Claim 2] The multi-slot roller made from the ceramics of the wire saw characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm² or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama.

[Claim 3] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.

[Claim 4] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics; this multi-slot roller made

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from the ceramics The composition of an alumina is formed with 50% or more of ceramics. The wire depth of flute of this multi-slot roller It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller slot is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.

[Claim 5] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics; this multi-slot roller made from the ceramics It is formed with the ceramics with a flexural strength of 3500kg/cm² or more. The wire depth of flute of this multi-slot roller It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.

[Claim 6] Claims 1, 2, 3, and 4 to which dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics is characterized by being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 7] Claims 1, 2, 3, and 4 to which accumulation of the error of the slot pitch of the one multi-slot roller made from the ceramics is characterized by being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 8] Claims 1, 2, 3, and 4 characterized by for dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics being 30 micrometers or less, and accumulation of the error of the pitch of this wire slot being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 9] Claims 3 and 4 characterized by the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 10] Claims 3 and 4 characterized by the mutual cumulative error of the slot pitch of the wire slot which faces of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 11] Claims 3 and 4 characterized by for the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, and the mutual

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cumulative error of the slot of this wire slot that faces being 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] When this invention is further described about the wire saw which cuts silicon, the magnetic substance, Xtal, etc., it relates to the multi-slot roller made from the ceramics of a wire saw.

[0002]

[Description of the Prior Art] The wire saw is equipped with two or more multi-slot rollers which stretched the wire, and cuts workpieces (work piece), such as silicon, the magnetic substance, Xtal, and ceramics, by rotating this multi-slot roller and carrying out rectilinear motion of this wire.

[0003] The conventional multi-slot roller is formed with resin, for example, nylon, and two or more wire slots are established in the front face. Although usually formed in 0.5-1mm, since that quality of the material is flexible and workability is also good, while processing of a wire slot is easy for this wire depth of flute, since it tends to wear it out, it has a problem in endurance. Then, in order to solve said problem in recent years, the roller made from the ceramics is used (refer to JP,63-237863,A).

[0004]

[Problem(s) to be Solved by the Invention] The degree of hardness of the ceramics is remarkably high compared with nylon, for example, although the Rockwell hardness of 66 nylon is R112, since the degree of hardness of the ceramics whose content of an alumina is 97% is too high, the measurement with Rockwell hardness is impossible. Then, it was Hv1400 when the Vickers hardness of this ceramics was measured. This Hv1400 is too high and the comparison with Rockwell hardness cannot do it.

[0005] Deformation of a wire expanded and contracted, and when the wire slot of a multi-slot roller was formed from nylon, the wire slot was compensating the precision error of a wire slot. However, since a wire slot does not deform when this wire slot is

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formed with the ceramics, only when a wire expands and contracts all the precision errors of a wire slot, it must compensate. Many [therefore, / when a wire slot is formed with the ceramics / farther than the case where the stress concerning a wire has a wire slot formed from nylon]

[0006] The multi-slot roller made from the ceramics of a wire saw must form a wire slot from the above-mentioned situation in a precision far higher than the multi-slot roller made of nylon.

[0007] The multi-slot roller made of nylon had processed the wire slot by cutting by the cutting tool using NC engine lathe. However, when processing the wire slot of the roller made from the ceramics, since a degree of hardness is very high, the ceramics becomes a grinding process by the diamond wheel using NC cylindrical grinder as mentioned above. Therefore, while the time amount which processing takes compared with the conventional example becomes remarkably long, processing costs also come to increase.

[0008] Moreover, grinding stones may have to be exchanged, as wear at the tip of a grinding stone is intense and is recessing of the one multi-slot roller made from the ceramics. However, if this grinding stone is exchanged, it will be difficult to double with the condition in front of exchange of the physical relationship of a wire slot and this grinding stone precisely, and it will become the error factor of the slot pitch of a result wire slot. Therefore, a wire slot cannot be precisely formed as a design, but it may become the cause of derailment and an open circuit.

[0009] Then, it is possible by making the wire depth of flute shallower than the conventional multi-slot roller made of nylon to solve said problem. However, if a wire slot is made shallow, it will become easy to generate derailment of a wire, and if a wire derails, the workpiece under cutting (work piece) will be spoiled.

[0010] Moreover, since the multi-slot roller made from the ceramics does not almost have deformation as mentioned above, high tension is used for a wire from the multi-slot roller made of nylon in many cases for the improvement in process tolerance, and the improvement in working speed, hanging on it. Furthermore, in order that this multi-slot roller may reduce the amount of shaving of a workpiece (work piece), and in order to cut much quantity at once, the wire of a thin path, for example, piano wire with a diameter of 0.1mm, is used. Therefore, if many loads are applied to a wire even when it is smaller than a design value on a wire, it will disconnect.

[0011] Furthermore, in recent years, diversification of a workpiece (work piece) progresses and the slot pitch of the wire slot demanded in connection with it is also crossed to a variety. When processing a workpiece into ultrathin especially, less than [slot pitch 0.2mm] is required, but if this slot pitch becomes small, naturally in proportion to it, slot Mayama's summit-of-the-mountain flight width will also become small. However, since the multi-slot roller made from the ceramics is a hard and brittle

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nature ingredient, if a sum of the mountain flight width is made small, a chipping will generate it in slot Mayama at the time of wire recessing. Therefore, it becomes difficult to form slot Mayama as a design. When slot Mayama cannot form as a design, derailment of a wire and an open circuit occur or it has a bad influence also on the process tolerance of a workpiece (work piece).

[0012] This invention is making it a chipping not occur in view of the above-mentioned situation at the time of recessing. Other purposes aim at making it derailment and an open circuit not arise while they make the wire depth of flute shallower than that of the conventional example.

[0013]
[Means for Solving the Problem] the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the content of an alumina for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on the front face -- it comes out. the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm² or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama -- it is.

[0014] Two or more multi-slot rollers which this invention has two or more wire slots on a front face, and are arranged in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of multi-slot rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, the multi-slot roller made from the ceramics of the wire saw by which it is characterized -- it comes out. In this invention dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics So that it may be 30 micrometers or less and accumulation of the error of the pitch of this wire slot may be 30 micrometers or less form or Moreover, you may form so that the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece may be 60 micrometers or less and the mutual cumulative error of the slot pitch which this wire slot faces may be 60 micrometers or less.

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[0015]

[Embodiment of the Invention] When this invention person was narrow, for example, slot Mayama's summit-of-the-mountain flight width was set to 40 micrometers or less, he experimented in whether a chipping occurs or not, having thought that that a chipping occurs would not have a problem in the quality of the material, and changing the content of an alumina component. Consequently, when the content of an alumina became 90% or more and flexural strength became 3500kg/cm² or more, it turned out that a chipping does not occur, for example even if set to 40 micrometers even if slot Mayama's summit-of-the-mountain flight width becomes narrow. Then, we decided that the content of an alumina adopts 90% or more of ceramics, or the ceramics with a flexural strength of 3500kg/cm² or more as the quality of the material of the multi-slot roller made from the ceramics.

[0016] what a wire tends to derail or disconnect this invention person to in the case of the multi-slot roller made from the ceramics -- a wire slot -- the multi-slot roller made of nylon -- comparing -- deformation -- **** -- I thought that it was because it is few. That is, although the wire slot is compensating precision, such as a deflection of the wire slot of a multi-slot roller, with the multi-slot roller made of nylon when deformation or a wire develops, most adjustments by deformation of a wire slot cannot be found, and are compensating all precision with the multi-slot roller made from the ceramics only with the wire.

[0017] Although what is necessary is just to form a wire slot precisely so that it may be without error to a design value in order to prevent derailment of a wire, and an open circuit, it is very difficult to form such. Then, when this invention person pursued the cause of derailment and an open circuit, it turned out that the main cause is in the deflection (henceforth the deflection of the axial direction) of the axial direction of the wire slot to the green sand core shaft of a multi-slot roller, and the deflection (henceforth the deflection of a radial direction) of the radial direction of the wire slot to the green sand core shaft of a multi-slot roller.

[0018] Then, even if these deflections arose, when it asked for the range which is not derailed and disconnected, i.e., the tolerance of a deflection, 20 micrometers or less of deflections of 20 micrometers or less and a radial direction came out [the wire depth of flute / the deflection of the axial direction] in the wire slot of the 50-500-micrometer multi-slot roller made from the ceramics, and a certain thing was understood.

[0019] Furthermore, when the following conditions were fulfilled, it turned out that it is more desirable.

(1) The path of the bay which connects the point that the path and wire of the path of the wire slot of an one multi-slot roller, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and ***** should be 30 micrometers or less.

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(2) The path of the bay which connects the point that the path and wire of the diameter of the wire slot of each of this **** roller of the two multi-slot roller made from the ceramics which counters a workpiece, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and the sum total of ***** should be 60 micrometers or less.

[0020] (3) The slot pitch cumulative error of the wire slot of an one multi-slot roller should be 30 micrometers or less.

(4) The cumulative error of the slot pitch of the wire slot where the two multi-slot roller made from the ceramics which counters a workpiece faces should be 60 micrometers or less. Then, it decided to adopt the wire slot in the above tolerance as processing conditions.

[0021] In addition, although the wire slot of the multi-slot roller made from the ceramics must be formed so that a wire can be attached, **** selection of the configuration, magnitude, the number, etc. is made if needed. For example, it is made a configuration to which a wire contacts the groove bottom of a wire slot, and is formed in a configuration to which a wire contacts the both-sides wall of a wire slot.

[0022] Moreover, 90% or more of purity, i.e., the content of an alumina, is used for 90% or more of ceramics, a zirconia, silicon carbide, silicon nitride, etc. as ceramics which forms a multi-slot roller.

[0023]

[Example 1] Drawing 1 - drawing 6 explain the first example of this invention. the multi-slot roller 1 made from the ceramics of a wire saw is formed in the bell shape with the ceramics, the outer diameter D comes out 40mm, and the bore of $1d$ comes out out of 20mm and die length L_n 100mm. As this ceramics, the ceramics whose content of an alumina is 90 97%% or more, for example, purity, is used.

[0024] The reinforcement member 5 is formed in the centrum 2 of this multi-slot roller 1. This reinforcement member 5 is the disk configuration of the shape of the said heart formed in this multi-slot roller 1 and one. $5t$ in thickness of the reinforcement member 5 of this disk configuration -- the same thickness as thickness $1t=10\text{mm}$ of the multi-slot roller 1 -- it comes out, it is, and although both ratio of wall thickness to outside diameter $1t/5t$ is 1, this ratio of wall thickness to outside diameter $1t/5t$ is chosen in consideration of the rigidity of a multi-slot roller etc.

[0025] Although one reinforcement member 5 of a disk configuration is formed, when **** selection also of this arrangement number is made in consideration of the die length L_n of this multi-slot roller 1 etc., for example, the reinforcement member 5 of three disk configurations is arranged in the direction of green sand core shaft C at equal intervals, the reinforcement member 5 may be omitted conversely.

[0026] In the reinforcement member 5 of a disk configuration, five holes 6 for

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lightweight-izing are established, and lightweight-ization of the reinforcement member 5 is attained by this hole 6 for lightweight-izing to it. In consideration of the rigidity of the multi-slot roller 1 demanded, **** selection of the location of this hole 6 for lightweight-izing, the number, the configuration, etc. is made, for example, the hole 6 for lightweight-izing has not penetrated, or the eight polygon-like holes 6 for lightweight-izing are adopted.

[0027] Spacing is set in surface 1a of this multi-slot roller, and two or more wire slots 10 are formed in the direction of green sand core shaft C at it. This wire slot 10 is precisely processed based on engineering drawing with NC cylindrical grinder which is not illustrated. For example, the wire channel depth $10d=0.12\text{mm}$, the slot include angle of $\theta=60$ degrees, the slot pitch of $P=0.24\text{mm}$, a flute width = it is formed in 0.2mm , slot Mayama's summit-of-the-mountain flight width of $W=0.04\text{mm}$, and 296 slots.

[0028] The metal supporter material 30 formed disc-like is formed in both-ends 1e of this multi-slot roller 1. A shank 31 is arranged in the center section of outside 30a of this metal supporter material 30, and the fitting section 33 is formed in the periphery section of the inside 30b. Although fitting of this fitting section 33 is carried out to edge 1e of the multi-slot roller 1, these both sections 33 and 1e are pasted up with the adhesives 35, such as an epoxy resin.

[0029] Since these Ryobe's 33 and 1e junction die length L_{33} is very shorter than the die length L_n of the multi-slot roller 1, a temperature change arises by operating the equipment of a wire saw, and even if both expand, contract and displace, Ryobe's junction condition is maintained. In addition, as for this metal supporter material 30, it is desirable to be formed in a disk configuration with the ingredient of coefficient of thermal expansion [**** / the same as that of the coefficient of thermal expansion of the ceramics or], although iron, steel, etc. are generally used, for example, titanium, a titanium alloy, etc. are used as this ingredient.

[0030] Next, actuation of a wire saw is explained. The multi-slot roller attachment part of the wire saw which is not illustrated is equipped with the shank 31 of the multi-slot roller 1. The wire 50 of one 0.12mm diameter is twisted around the wire slot 10 which faces, surrounding two or more of these multi-slot rollers 1 with which it was equipped, and much wire train 50A is formed. at this time, dispersion with a diameter [the diameter of $10n$ of the wire slot of an one multi-slot roller], i.e., the diameter of wire groove bottom $10R$, and a diameter [of bay $10W$ which connect the contacting point that $10f$ of side attachment walls and the wire of both sides of a wire slot contact] of $10m$ is 30 micrometers or less, and 30 micrometers or less of cumulative errors of the slot pitch P of this wire slot come out.

[0031] Moreover, the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters the

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workpiece currently used within 1 equipment, Namely, the diameter of 10n of wire groove bottom 10R of each multi-slot roller made from the ceramics, The sum total of dispersion with a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 60 micrometers or less, and the accumulation of the mutual error of the slot pitch P which the multi-slot roller made from the ceramics which faces faces is 60 micrometers or less.

[0032] Round trip or one direction rectilinear motion of the wire train 50A is carried out like an arrow head A50 by reversal-going or one direction rotating a multi-slot roller. the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of the multi-slot roller 1 made from the ceramics at this time is 20 micrometers or less, and 20 micrometers or less of deflections of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 made from the ceramics come out of it.

[0033] While pressing Workpiece (work piece) BW against this wire 50, abrasives are cut from the regurgitation nozzle which is not illustrated, making an abrasive material intervene between discharge and both.

[0034] Although inertial force occurs with rotation of this multi-slot roller 1 made from the ceramics, since this multi-slot roller 1 is very lightweight compared with the conventional example, it will become very small [that inertial force].

[0035] Moreover, although a temperature change may arise at the time of operation of a wire saw and both this multi-slot roller 1 made from the ceramics and the metal supporter material 30 may expand and contract, if both 1 and 30 are in abbreviation etc. by carrying out and coefficient of thermal expansion is made from them, since it expands and contracts in coincidence at an abbreviation same rate and the exfoliation like jointing etc. will not occur, it is desirable.

[0036] Although the deflection of a wire slot occurs at the time of operation of the above-mentioned wire saw, the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less, and the deflection of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less.

[0037] As a result of performing cutting processing of the silicon whose diameter is 8 inches in the wire saw which used the above-mentioned multi-slot roller made from the ceramics, derailment of a wire, an open circuit, etc. did not occur, and exfoliation of the ceramic section and metal supporter material etc. was not seen, but the dimensional accuracy of the wafer which is a workpiece was able to maintain 5 micrometers or more, and was able to be processed.

[0038] The tolerance of the deflection of the wire slot of radial direction AR to the green sand core shaft C of the multi-slot roller 1 made from the ceramics in this example is called for also by count. The tolerance of this deflection shows the limitation of the

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deflection which derailment generates.

[0039] Next, said tolerance is calculated by drawing 6 which is the derailment nomogram of this example. Although various causes are put together and derailment of the wire of a wire saw is generated, the progress of the derailment is as follows.

(1) In order that the wire which has run from the next wire slot may enter aslant to a wire slot, a wire 50 contacts 10f of side attachment walls of this wire slot like [near B of drawing 6].

[0040] (2) This wire receives rotation of the multi-slot roller 1 made from the ceramics, and the force to the direction of a periphery of 10f of side attachment walls.

(3) The green sand core shaft C spacing L between the two multi-slot rollers which counters becomes short by the deflection of radial direction AR of the wire slot of the multi-slot roller made from the ceramics, and a wire 50 loosens and derails.

[0041] The following relational expression is called for from drawing 6 which shows the time of this derailment.

$$Y+z=L+l+\delta x \quad (1)$$

$$\cos\theta=r/(r+t) \quad (2)$$

$$l=2\pi r x \theta / 360 \quad (3)$$

$$r^2+z^2=(r+t)^2 \quad (4)$$

$$(L-\delta x)^2+t^2=y^2 \quad (5)$$

[0042] In the above-mentioned formula, the amount of deflections of the wire slot of a precise distance, the die length of l:radii, an r:multi-slot roller, and the radius of the contact part of a wire, the wire migration length at the time of t:derailment initiation and a delta x:multi-slot roller is shown theoretically between L:multi-slot rollers, respectively.

[0043] The above-mentioned formula (1) From - (5), the deflection of the wire slot of the multi-slot roller which derailment generates is searched for. Next, the example of count is shown.

The example 1 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment generates.

$$L= 100 \text{ Unit [mm]}$$

$$r= 20t=0.4[0044]$$

$$(2) \text{ Formula } \cos\theta=20/(20+0.4)=0.98039 \text{ Theta}=\cos^{-1}0.98039= 11.365 \text{ degrees}$$

$$(3) \text{ types } l=2\pi \times 20 \times 11.365 / 360= 3.9671 \quad (4) \text{ types } Z=\sqrt{(r+t)^2-r^2}$$

$$= \sqrt{(20+0.4)^2-20^2}$$

$$= 4.0200 [0045] \text{ From (1) and (5) types } (L-\delta x)^2+t^2=(L+l+\delta x-z)^2 \text{ therefore}$$

$$(100-\delta x)^2+0.4^2=(100+3.967-4.0200+\delta x)^2 \quad [2] \quad 10000-200\delta x+\delta x^2+0.16$$

$$=9989.4028+199.894\delta x+2\delta x^2 \text{ therefore } \delta x^2+399.894\delta x-10.757=0$$

$$\delta x=26.9[\mu\text{m}] [0046] \text{ The example 2 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment}$$

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generates.

$L = 100$ Unit [mm]

$r =$ It calculates like the example 1 of $30t = 0.4$ count, and is $\text{deltax} = 21.7$ [mum].

[0047] Although the amount Δx of deflections of the wire slot of the multi-slot roller made from the ceramics was calculated by the above-mentioned example of count, as for the deflection of radial direction AR of a wire slot to the green sand core shaft C of the multi-slot roller made from the ceramics, it is desirable to manufacture so that it may be set to 20 micrometers or less from said examples 1 and 2 of count.

[0048]

[Example 2] Drawing 7 explains the 2nd example of this invention. The difference of this example and 1st example is as follows. the cross-section configuration of the wire slot 10 -- setting -- slot include-angle $\theta_1 = 90$ degree of a base, and the slot include angle θ of a side attachment wall -- they are $2 = 10$ degrees, the flute width of $B = 0.3$ mm, slot Mayama's summit-of-the-mountain flight width of $W = 0.1$ mm, channel depth $10d = 0.3$ mm, and slot pitch $= 0.4$ mm.

[0049]

[Example 3] Drawing 8 explains the 3rd example of this invention. The next experiment was conducted in order to know the relation between the alumina content (purity %) of the multi-slot roller made from the ceramics or flexural strength, and the summit-of-the-mountain flight width of slot Mayama whom a chipping does not generate at the time of processing. As shown in drawing 8, the maximum summit-of-the-mountain flight width W as which 1 micrometer of wire slots 10 of the same configuration is narrowed from each pitch 0.4mm on the multi-slot roller 1 made from the ceramics with which alumina contents differ, and generating of a chipping is regarded in this each **** roller was investigated. In addition, the processing conditions are as follows.

[0050] processing machine: -- NC cylindrical-grinder grinding stone: -- the result of a diamond wheel, the grain-size #400 processing work-piece (alumina material): diameter of 65mm, the die-length rotational frequency [of 100mm] 200rpm processing quirk-like: slot include angle of $\theta = 60$ degrees, and a channel depth $10d = 0.15$ mm experiment is shown in Table 1 and drawing 9, and drawing 10.

[0051]

[Table 1]

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アルミナ純度 (%)	チッピング発生最大山幅 (μm)				曲げ強度 (kg/cm^2)
	実験 1	実験 2	実験 3	平均	
75	99	93	84	92.0	2300
88	82	72	73	75.6	2700
90	31	34	31	32.0	3500
97	44	45	32	40.3	4100
99.5	18	13	19	16.7	3600

[0052] Drawing 9 is drawing showing the relation between an alumina content (axis-of-abscissa %), i.e., alumina purity, and a chipping generating summit-of-the-mountain flight width (axis-of-ordinate μm). In this drawing, as for the 2nd experimental result and the trigonum mark, the 1st experimental result and the square mark show an average for a round mark, as for the 3rd experimental result and x mark.

[0053] Drawing 10 is drawing showing the relation between alumina purity (axis-of-abscissa %), a chipping generating summit-of-the-mountain flight width (left axis-of-ordinate μm), and flexural strength (right axis-of-ordinate kg/cm^2). In this drawing, the square mark shows a summit-of-the-mountain flight width, and a round mark shows flexural strength.

[0054] Table 1 and drawing 9, and drawing 10 showed that 75% of alumina contents, 88% of thing or the flexural strength of $2300\text{kg}/\text{cm}^2$, and the summit-of-the-mountain flight width of a $2700\text{kg}/\text{cm}^2$ thing had the large quality of the material 2 or 3 or more times compared with the summit-of-the-mountain flight width of a thing (90% of alumina purity, 92%, 97%, and 99.5% of thing or the flexural strength of $3500\text{kg}/\text{cm}^2$, $4100\text{kg}/\text{cm}^2$, and $3600\text{kg}/\text{cm}^2$). That is, it turned out that a chipping does not occur even if it will make extremely narrow the summit-of-the-mountain flight width W, if the content of an alumina becomes 90% or more or the flexural strength of $3500\text{kg}/\text{cm}^2$ or more.

[0055]

[Example 4] The 4th example of this invention is explained. The chipping was not generated, although the diamond wheel was used for the multi-slot roller with a diameter of 60mm which consists of an alumina of 97% of purity made from the ceramics and the wire slot with a slot pitch [of $P=0.3\text{mm}$] and a summit-of-the-mountain flight width [of

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slot Mayama] of $W = 50$ micrometers was processed into it. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of Xtal was performed, cutting with a as precise thickness precision as 5 micrometers or more was performed. Although the wire slot was ground faint [every] with the abrasive grain adhering to a wire and was worn out, it was able to maintain the above-mentioned precision over the long time of 300 hours, and was able to perform cutting processing.

[0056]

[Example 5] The 5th example of this invention is explained. Although the diamond wheel was used for the multi-slot roller made from the ceramics of the same specification as the above which consists of an alumina of 97% of purity and the wire slot with a wire slot pitch [of $P = 0.25\text{mm}$] and a summit-of-the-mountain flight width [of slot Mayama] of $W = 40$ micrometers was processed into it, the chipping was not generated like the example 4. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of the magnetic substance was performed, it came out to maintain 5 micrometers or more like the above, and the thickness precision of a work piece came.

[0057]

[Example 6] Drawing 11 explains the 6th example of this invention. A roller does not necessarily need to form all with said ceramics, and if the slot formation part is formed with said ceramics, it is sufficient for it. The example is as follows.

(1) As shown in drawing 11 (A), form the cylindrical periphery section 81 made from said ceramics with which the wire slot 10 stuck to the metal pipe 80. The stop member 83 for an applied part 82 being formed in the both ends of this metallic pipe 80, and fixing the periphery section 81 to an end is formed.

[0058] (2) As shown in drawing 11 (B), form the cylindrical periphery section 91 made from said ceramics with which the wire slot 10 stuck to the metal pipe 90. The **-like ring part 92 is formed, the reinforcement disk 95 with which the hole 94 opened is formed in a centrum 93, and the lid 96 which fixes this periphery section 91 is fixed to other end 90b by end 90a.

[0059]

[Example 7] Drawing 12 explains the 7th example of this invention. A slot formation part is formed with said ceramics, and this example as well as said 6th example is a case.

(3) As shown in drawing 12 (A), form the cylindrical periphery section 101 made from said ceramics with which the wire slot 10 stuck to the metal pipe 100. The bearing shank 105 is formed in end 2100a of this metal pipe 100, and the truncated-cone-like bearing 106 is formed in other end 100b. The cylindrical crevice 107 is formed in the periphery of this pipe 100, and said cylindrical periphery section 101 is being attached and fixed to this crevice 107.

[0060] (4) As shown in drawing 12 (B), form the cylindrical periphery section 111 made

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from said ceramics with which the wire slot 10 stuck to the metal pipe 110. The truncated-cone-like bearings 115 and 116 are formed in the both ends of this metal pipe 110. The cylindrical crevice 117 is formed in the periphery of this pipe 110, and said cylindrical periphery section 111 is attached and fixed to it by this crevice 117.

[0061]

[Example 8] Drawing 13 explains the 7th example of this invention. In said example, although the slot formation part was formed with said ceramics, this whole multi-slot roller made from the ceramics can also be formed with said ceramics. The example is as follows.

(1) As shown in drawing 13 (A), form the bell shape roller 120 with said ceramics, and form the wire slot 10 in the periphery section 121 of this roller. Since this roller 120 does not have a reinforcement member into a centrum 123 unlike said 1st example, in order to maintain reinforcement, that thickness R_t is thicker than that of the 1st example, for example, is formed in twice as many thickness as this.

[0062] (2) As shown in drawing 13 (B), form the bell shape roller 130 with said ceramics, and form the wire slot 10 in the periphery section 131 of this roller 130. The bearing shank 135 is formed in the end of this roller 130, and the truncated-cone-like bearing 136 is formed in the other end. In addition, the bearing shank 135 is covered with the metal 138, in order to improve concordance with bearing.

[0063]

[Effect of the Invention] This invention does the following remarkable effectiveness so.

(1) Since the roller made from the ceramics is formed with the ceramics beyond alumina 90%, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.

[0064] (2) Since the roller made from the ceramics is formed with the ceramics with a flexural strength of 3500kg/cm² or more, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.

[0065] (3) Since this wire depth of flute is 50-500 micrometers, the deflection of the radial direction of the wire slot to the medial axis of this roller is 20 micrometers or less and the deflection of the axial direction of the wire slot to the medial axis of this roller is 20 micrometers or less; compared with the conventional example, the wire depth of flute becomes shallow, and even if it makes it shallow, neither derailment nor an open circuit occurs. Therefore, the floor to floor time and costs of a wire slot decrease remarkably compared with the conventional example.

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TECHNICAL FIELD

[Field of the Invention] When this invention is further described about the wire saw which cuts silicon, the magnetic substance, Xtal, etc., it relates to the multi-slot roller made from the ceramics of a wire saw.

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PRIOR ART

[Description of the Prior Art] The wire saw is equipped with two or more multi-slot rollers which stretched the wire, and cuts workpieces (work piece), such as silicon, the magnetic substance, Xtal, and ceramics, by rotating this multi-slot roller and carrying out rectilinear motion of this wire.

[0003] The conventional multi-slot roller is formed with resin, for example, nylon, and two or more wire slots are established in the front face. Although usually formed in 0.5-1mm, since that quality of the material is flexible and workability is also good, while processing of a wire slot is easy for this wire depth of flute, since it tends to wear it out, it has a problem in endurance. Then, in order to solve said problem in recent years, the roller made from the ceramics is used (refer to JP,63-237863,A).

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EFFECT OF THE INVENTION

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(1) Since the roller made from the ceramics is formed with the ceramics beyond alumina 90%, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.

[0064] (2) Since the roller made from the ceramics is formed with the ceramics with a flexural strength of 3500kg/cm² or more, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] The degree of hardness of the ceramics is remarkably high compared with nylon, for example, although the Rockwell hardness of 66 nylon is R112, since the degree of hardness of the ceramics whose content of an alumina is 97% is too high, the measurement with Rockwell hardness is impossible. Then, it was Hv1400 when the Vickers hardness of this ceramics was measured. This Hv1400 is too high and the comparison with Rockwell hardness cannot do it.

[0005] Deformation of a wire expanded and contracted, and when the wire slot of a multi-slot roller was formed from nylon, the wire slot was compensating the precision error of a wire slot. However, since a wire slot does not deform when this wire slot is formed with the ceramics, only when a wire expands and contracts all the precision errors of a wire slot, it must compensate. Many [therefore, / when a wire slot is formed with the ceramics / farther than the case where the stress concerning a wire has a wire slot formed from nylon]

[0006] The multi-slot roller made from the ceramics of a wire saw must form a wire slot from the above-mentioned situation in a precision far higher than the multi-slot roller made of nylon.

[0007] The multi-slot roller made of nylon had processed the wire slot by cutting by the cutting tool using NC engine lathe. However, when processing the wire slot of the roller made from the ceramics, since a degree of hardness is very high, the ceramics becomes a grinding process by the diamond wheel using NC cylindrical grinder as mentioned above. Therefore, while the time amount which processing takes compared with the conventional example becomes remarkably long, processing costs also come to increase.

[0008] Moreover, grinding stones may have to be exchanged, as wear at the tip of a grinding stone is intense and is recessing of the one multi-slot roller made from the ceramics. However, if this grinding stone is exchanged, it will be difficult to double with the condition in front of exchange of the physical relationship of a wire slot and this

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grinding stone precisely, and it will become the error factor of the slot pitch of a result wire slot. Therefore, a wire slot cannot be precisely formed as a design, but it may become the cause of derailment and an open circuit.

[0009] Then, it is possible by making the wire depth of flute shallower than the conventional multi-slot roller made of nylon to solve said problem. However, if a wire slot is made shallow, it will become easy to generate derailment of a wire, and if a wire derails, the workpiece under cutting (work piece) will be spoiled.

[0010] Moreover, since the multi-slot roller made from the ceramics does not almost have deformation as mentioned above, high tension is used for a wire from the multi-slot roller made of nylon in many cases for the improvement in process tolerance, and the improvement in working speed, hanging on it. Furthermore, in order that this multi-slot roller may reduce the amount of shaving of a workpiece (work piece), and in order to cut much quantity at once, the wire of a thin path, for example, piano wire with a diameter of 0.1mm, is used. Therefore, if many loads are applied to a wire even when it is smaller than a design value on a wire, it will disconnect.

[0011] Furthermore, in recent years, diversification of a workpiece (work piece) progresses and the slot pitch of the wire slot demanded in connection with it is also crossed to a variety. When processing a workpiece into ultrathin especially, less than [slot pitch 0.2mm] is required, but if this slot pitch becomes small, naturally in proportion to it, slot Mayama's summit-of-the-mountain flight width will also become small. However, since the multi-slot roller made from the ceramics is a hard and brittle nature ingredient, if a summit-of-the-mountain flight width is made small, a chipping will generate it in slot Mayama at the time of wire recessing. Therefore, it becomes difficult to form slot Mayama as a design. When slot Mayama cannot form as a design, derailment of a wire and an open circuit occur or it has a bad influence also on the process tolerance of a workpiece (work piece).

[0012] This invention is making it a chipping not occur in view of the above-mentioned situation at the time of recessing. Other purposes aim at making it derailment and an open circuit not arise while they make the wire depth of flute shallower than that of the conventional example.

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MEANS

[Means for Solving the Problem] the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the content of an alumina for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on the front face -- it comes out. the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm² or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama -- it is.

[0014] Two or more multi-slot rollers which this invention has two or more wire slots on a front face, and are arranged in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of multi-slot rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, the multi-slot roller made from the ceramics of the wire saw by which it is characterized -- it comes out. In this invention dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics So that it may be 30 micrometers or less and accumulation of the error of the pitch of this wire slot may be 30 micrometers or less form or Moreover, you may form so that the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece may be 60 micrometers or less and the

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mutual cumulative error of the slot pitch which this wire slot faces may be 60 micrometers or less.

[0015]

[Embodiment of the Invention] When this invention person was narrow, for example, slot Mayama's summit-of-the-mountain flight width was set to 40 micrometers or less, he experimented in whether a chipping occurs or not, having thought that that a chipping occurs would not have a problem in the quality of the material, and changing the content of an alumina component. Consequently, when the content of an alumina became 90% or more and flexural strength became 3500kg/cm² or more, it turned out that a chipping does not occur, for example even if set to 40 micrometers even if slot Mayama's summit-of-the-mountain flight width becomes narrow. Then, we decided that the content of an alumina adopts 90% or more of ceramics, or the ceramics with a flexural strength of 3500kg/cm² or more as the quality of the material of the multi-slot roller made from the ceramics.

[0016] what a wire tends to derail or disconnect this invention person to in the case of the multi-slot roller made from the ceramics -- a wire slot -- the multi-slot roller made of nylon -- comparing -- deformation -- **** -- I thought that it was because it is few. That is, although the wire slot is compensating precision, such as a deflection of the wire slot of a multi-slot roller, with the multi-slot roller made of nylon when deformation or a wire develops, most adjustments by deformation of a wire slot cannot be found, and are compensating all precision with the multi-slot roller made from the ceramics only with the wire.

[0017] Although what is necessary is just to form a wire slot precisely so that it may be without error to a design value in order to prevent derailment of a wire, and an open circuit, it is very difficult to form such. Then, when this invention person pursued the cause of derailment and an open circuit, it turned out that the main cause is in the deflection (henceforth the deflection of the axial direction) of the axial direction of the wire slot to the green sand core shaft of a multi-slot roller, and the deflection (henceforth the deflection of a radial direction) of the radial direction of the wire slot to the green sand core shaft of a multi-slot roller.

[0018] Then, even if these deflections arose, when it asked for the range which is not derailed and disconnected, i.e., the tolerance of a deflection, 20 micrometers or less of deflections of 20 micrometers or less and a radial direction came out [the wire depth of flute / the deflection of the axial direction] in the wire slot of the 50-500-micrometer multi-slot roller made from the ceramics, and a certain thing was understood.

[0019] Furthermore, when the following conditions were fulfilled, it turned out that it is more desirable.

(1) The path of the bay which connects the point that the path and wire of the path of the

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wire slot of an one multi-slot roller, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and ***** should be 30 micrometers or less.

(2) The path of the bay which connects the point that the path and wire of the diameter of the wire slot of each of this **** roller of the two multi-slot roller made from the ceramics which counters a workpiece, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and the sum total of ***** should be 60 micrometers or less.

[0020] (3) The slot pitch cumulative error of the wire slot of an one multi-slot roller should be 30 micrometers or less.

(4) The cumulative error of the slot pitch of the wire slot where the two multi-slot roller made from the ceramics which counters a workpiece faces should be 60 micrometers or less. Then, it decided to adopt the wire slot in the above tolerance as processing conditions.

[0021] In addition, although the wire slot of the multi-slot roller made from the ceramics must be formed so that a wire can be attached, **** selection of the configuration, magnitude, the number, etc. is made if needed. For example, it is made a configuration to which a wire contacts the groove bottom of a wire slot, and is formed in a configuration to which a wire contacts the both-sides wall of a wire slot.

[0022] Moreover, 90% or more of purity, i.e., the content of an alumina, is used for 90% or more of ceramics, a zirconia, silicon carbide, silicon nitride, etc. as ceramics which forms a multi-slot roller.

[0023]

[Example 1] Drawing 1 - drawing 6 explain the first example of this invention. the multi-slot roller 1 made from the ceramics of a wire saw is formed in the bell shape with the ceramics, the outer diameter D comes out 40mm, and the bore of 1d comes out out of 20mm and die length Ln 100mm. As this ceramics, the ceramics whose content of an alumina is 90 97%% or more, for example, purity, is used.

[0024] The reinforcement member 5 is formed in the centrum 2 of this multi-slot roller 1. This reinforcement member 5 is the disk configuration of the shape of the said heart formed in this multi-slot roller 1 and one. 5t in thickness of the reinforcement member 5 of this disk configuration -- the same thickness as thickness 1t=10mm of the multi-slot roller 1 -- it comes out, it is, and although both ratio of wall thickness to outside diameter $1t/5t$ is 1, this ratio of wall thickness to outside diameter $1t/5t$ is chosen in consideration of the rigidity of a multi-slot roller etc.

[0025] Although one reinforcement member 5 of a disk configuration is formed, when **** selection also of this arrangement number is made in consideration of the die length Ln of this multi-slot roller 1 etc., for example, the reinforcement member 5 of three disk configurations is arranged in the direction of green sand core shaft C at equal intervals,

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the reinforcement member may be omitted conversely.

[0026] In the reinforcement member 5 of a disk configuration, five holes 6 for lightweight-izing are established, and lightweight-ization of the reinforcement member 5 is attained by this hole 6 for lightweight-izing to it. In consideration of the rigidity of the multi-slot roller 1 demanded, **** selection of the location of this hole 6 for lightweight-izing, the number, the configuration, etc. is made, for example, the hole 6 for lightweight-izing has not penetrated, or the eight polygon-like holes 6 for lightweight-izing are adopted.

[0027] Spacing is set in surface 1a of this multi-slot roller, and two or more wire slots 10 are formed in the direction of green sand core shaft C at it. This wire slot 10 is precisely processed based on engineering drawing with NC cylindrical grinder which is not illustrated. For example, the wire channel depth $10d=0.12\text{mm}$, the slot include angle of $\theta=60$ degrees, the slot pitch of $P=0.24\text{mm}$, a flute width = it is formed in 0.2mm , slot Mayama's summit-of-the-mountain flight width of $W=0.04\text{mm}$, and 296 slots.

[0028] The metal supporter material 30 formed disc-like is formed in both-ends 1e of this multi-slot roller 1. A shank 31 is arranged in the center section of outside 30a of this metal supporter material 30, and the fitting section 33 is formed in the periphery section of the inside 30b. Although fitting of this fitting section 33 is carried out to edge 1e of the multi-slot roller 1, these both sections 33 and 1e are pasted up with the adhesives 35, such as an epoxy resin.

[0029] Since these Ryobe's 33 and 1e junction die length L_{33} is very shorter than the die length L_n of the multi-slot roller 1, a temperature change arises by operating the equipment of a wire saw, and even if both expand, contract and displace, Ryobe's junction condition is maintained. In addition, as for this metal supporter material 30, it is desirable to be formed in a disk configuration with the ingredient of coefficient of thermal expansion [**** / the same as that of the coefficient of thermal expansion of the ceramics or], although iron, steel, etc. are generally used, for example, titanium, a titanium alloy, etc. are used as this ingredient.

[0030] Next, actuation of a wire saw is explained. The multi-slot roller attachment part of the wire saw which is not illustrated is equipped with the shank 31 of the multi-slot roller 1. The wire 50 of one 0.12mm diameter is twisted around the wire slot 10 which faces, surrounding two or more of these multi-slot rollers 1 with which it was equipped, and much wire train 50A is formed. at this time, dispersion with a diameter [the diameter of $10n$ of the wire slot of an one multi-slot roller], i.e., the diameter of wire groove bottom $10R$, and a diameter [of bay $10W$ which connect the contacting point that $10f$ of side attachment walls and the wire of both sides of a wire slot contact] of $10m$ is 30 micrometers or less, and 30 micrometers or less of cumulative errors of the slot pitch P of this wire slot come out.

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[0031] Moreover, the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters the workpiece currently used within 1 equipment, Namely, the diameter of 10n of wire groove bottom 10R of each multi-slot roller made from the ceramics, The sum total of dispersion with a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 60 micrometers or less, and the accumulation of the mutual error of the slot pitch P which the multi-slot roller made from the ceramics which faces faces is 60 micrometers or less.

[0032] Round trip or one direction rectilinear motion of the wire train 50A is carried out like an arrow head A50 by reversal-going or one direction rotating a multi-slot roller. the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of the multi-slot roller 1 made from the ceramics at this time is 20 micrometers or less, and 20 micrometers or less of deflections of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 made from the ceramics come out of it.

[0033] While pressing Workpiece (work piece) BW against this wire 50, abrasives are cut from the regurgitation nozzle which is not illustrated, making an abrasive material intervene between discharge and both.

[0034] Although inertial force occurs with rotation of this multi-slot roller 1 made from the ceramics, since this multi-slot roller 1 is very lightweight compared with the conventional example, it will become very small [that inertial force].

[0035] Moreover, although a temperature change may arise at the time of operation of a wire saw and both this multi-slot roller 1 made from the ceramics and the metal supporter material 30 may expand and contract, if both 1 and 30 are in abbreviation etc. by carrying out and coefficient of thermal expansion is made from them, since it expands and contracts in coincidence at an abbreviation same rate and the exfoliation like jointing etc. will not occur, it is desirable.

[0036] Although the deflection of a wire slot occurs at the time of operation of the above-mentioned wire saw, the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less, and the deflection of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less.

[0037] As a result of performing cutting processing of the silicon whose diameter is 8 inches in the wire saw which used the above-mentioned multi-slot roller made from the ceramics, derailment of a wire, an open circuit, etc. did not occur, and exfoliation of the ceramic section and metal supporter material etc. was not seen, but the dimensional accuracy of the wafer which is a workpiece was able to maintain 5 micrometers or more, and was able to be processed.

[0038] The tolerance of the deflection of the wire slot of radial direction AR to the green

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sand core shaft C of the multi-slot roller 1 made from the ceramics in this example is called for also by count. The tolerance of this deflection shows the limitation of the deflection which derailment generates.

[0039] Next, said tolerance is calculated by drawing 6 which is the derailment nomogram of this example. Although various causes are put together and derailment of the wire of a wire saw is generated, the progress of the derailment is as follows.

(1) In order that the wire which has run from the next wire slot may enter aslant to a wire slot, a wire 50 contacts 10f of side attachment walls of this wire slot like [near B of drawing 6].

[0040] (2) This wire receives rotation of the multi-slot roller 1 made from the ceramics, and the force to the direction of a periphery of 10f of side attachment walls.

(3) The green sand core shaft C spacing L between the two multi-slot rollers which counters becomes short by the deflection of radial direction AR of the wire slot of the multi-slot roller made from the ceramics, and a wire 50 loosens and derails.

[0041] The following relational expression is called for from drawing 6 which shows the time of this derailment.

$$Y+z=L+l+\Delta x \quad (1)$$

$$\cos\theta=r/(r+t) \quad (2)$$

$$l=2\pi r x \theta / 360 \quad (3)$$

$$r^2+z^2=(r+t)^2 \quad (4)$$

$$(L-\Delta x)^2+t^2=y^2 \quad (5)$$

[0042] In the above-mentioned formula, the amount of deflections of the wire slot of a precise distance, the die length of l:radial, an r:multi-slot roller, and the radius of the contact part of a wire, the wire migration length at the time of t:derailment initiation and a Δx :multi-slot roller is shown theoretically between L:multi-slot rollers, respectively.

[0043] The above-mentioned formula (1) From - (5), the deflection of the wire slot of the multi-slot roller which derailment generates is searched for. Next, the example of count is shown.

The example 1 of count: The conditions for calculating the amount Δx of deflections of the wire slot of the multi-slot roller which derailment generates.

$$L=100 \text{ Unit [mm]}$$

$$r=20 \quad t=0.4 \quad [0044]$$

$$(2) \text{ Formula } \cos\theta=20/(20+0.4)=0.98039 \quad \theta=\cos^{-1} 0.98039=11.365 \text{ degrees}$$

$$(3) \text{ types } l=2\pi \times 20 \times 11.365 / 360=3.9671 \quad (4) \text{ types } Z=\sqrt{(r+t)^2-r^2}$$

$$=\sqrt{(20+0.4)^2-20^2}$$

$$=4.0200 \quad [0045] \text{ From (1) and (5) types } (L-\Delta x)^2+t^2=(L+l+\Delta x-z)^2 \text{ therefore}$$

$$(100-\Delta x)^2+0.4^2=(100+3.967-4.0200+\Delta x)^2 \quad [2] \quad 10000-200\Delta x+\Delta x^2+0.16=9989.4028+199.894\Delta x+2\Delta x^2 \text{ therefore } \Delta x^2+399.894\Delta x-10.757=0$$

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deltax=26.9[mum] [0046] The example 2 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment generates.

L= 100 Unit [mm]

r= It calculates like the example 1 of 30t=0.4 count, and is deltax=21.7[mum].

[0047] Although the amount delta x of deflections of the wire slot of the multi-slot roller made from the ceramics was calculated by the above-mentioned example of count, as for the deflection of radial direction AR of a wire slot to the green sand core shaft C of the multi-slot roller made from the ceramics, it is desirable to manufacture so that it may be set to 20 micrometers or less from said examples 1 and 2 of count.

[0048]

[Example 2] Drawing 7 explains the 2nd example of this invention. The difference of this example and 1st example is as follows. the cross-section configuration of the wire slot 10 -- setting -- slot include-angle theta1=90 degree of a base, and the slot include angle theta of a side attachment wall -- they are 2= 10 degrees, the flute width of B= 0.3mm, slot Mayama's summit-of-the-mountain flight width of W= 0.1mm, channel depth 10d=0.3mm, and slot pitch =0.4mm.

[0049]

[Example 3] Drawing 8 explains the 3rd example of this invention. The next experiment was conducted in order to know the relation between the alumina content (purity %) of the multi-slot roller made from the ceramics or flexural strength, and the summit-of-the-mountain flight width of slot Mayama whom a chipping does not generate at the time of processing. As shown in drawing 8, the maximum summit-of-the-mountain flight width W as which 1 micrometer of wire slots 10 of the same configuration is narrowed from each pitch 0.4mm on the multi-slot roller 1 made from the ceramics with which alumina contents differ, and generating of a chipping is regarded in this each **** roller was investigated. In addition, the processing conditions are as follows.

[0050] processing machine: -- NC cylindrical-grinder grinding stone: -- the result of a diamond wheel, the-grain-size #400 processing work-piece (alumina material):diameter of 65mm, the die-length rotational frequency [of 100mm] 200rpm processing quirk-like:slot include angle of theta= 60 degrees, and a channel depth 10d= 0.15mm experiment is shown in Table 1 and drawing 9, and drawing 10.

[0051]

[Table 1]

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アルミナ純度 (%)	チッピング発生最大山幅 (μm)				曲げ強度 (kg/cm^2)
	実験 1	実験 2	実験 3	平均	
75	99	93	84	92.0	2300
88	82	72	73	75.6	2700
90	31	34	31	32.0	3500
97	44	45	32	40.3	4100
99.5	18	13	19	16.7	3600

[0052] Drawing 9 is drawing showing the relation between an alumina content (axis-of-abscissa %), i.e., alumina purity, and a chipping generating summit-of-the-mountain flight width (axis-of-ordinate μm). In this drawing, as for the 2nd experimental result and the trigonum mark, the 1st experimental result and the square mark show an average for a round mark, as for the 3rd experimental result and x mark.

[0053] Drawing 10 is drawing showing the relation between alumina purity (axis-of-abscissa %), a chipping generating summit-of-the-mountain flight width (left axis-of-ordinate μm), and flexural strength (right axis-of-ordinate kg/cm^2). In this drawing, the square mark shows a summit-of-the-mountain flight width, and a round mark shows flexural strength.

[0054] Table 1 and drawing 9, and drawing 10 showed that 75% of alumina contents, 88% of thing or the flexural strength of $2300\text{kg}/\text{cm}^2$, and the summit-of-the-mountain flight width of a $2700\text{kg}/\text{cm}^2$ thing had the large quality of the material 2 or 3 or more times compared with the summit-of-the-mountain flight width of a thing (90% of alumina purity, 92%, 97%, and 99.5% of thing or the flexural strength of $3500\text{kg}/\text{cm}^2$, $4100\text{kg}/\text{cm}^2$, and $3600\text{kg}/\text{cm}^2$). That is, it turned out that a chipping does not occur even if it will make extremely narrow the summit-of-the-mountain flight width W, if the content of an alumina becomes 90% or more or the flexural strength of $3500\text{kg}/\text{cm}^2$ or more.

[0055]

[Example 4] The 4th example of this invention is explained. The chipping was not generated, although the diamond wheel was used for the multi-slot roller with a diameter of 60mm which consists of an alumina of 97% of purity made from the ceramics and the wire slot with a slot pitch [of $P=0.3\text{mm}$] and a summit-of-the-mountain flight width [of

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slot Mayama] of $W = 50$ micrometers was processed into it. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of Xtal was performed, cutting with a as precise thickness precision as 5 micrometers or more was performed. Although the wire slot was ground faint [every] with the abrasive grain adhering to a wire and was worn out, it was able to maintain the above-mentioned precision over the long time of 300 hours, and was able to perform cutting processing.

[0056]

[Example 5] The 5th example of this invention is explained. Although the diamond wheel was used for the multi-slot roller made from the ceramics of the same specification as the above which consists of an alumina of 97% of purity and the wire slot with a wire slot pitch [of $P = 0.25\text{mm}$] and a summit-of-the-mountain flight width [of slot Mayama] of $W = 40$ micrometers was processed into it, the chipping was not generated like the example 4. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of the magnetic substance was performed, it came out to maintain 5 micrometers or more like the above, and the thickness precision of a work piece came.

[0057]

[Example 6] Drawing 11 explains the 6th example of this invention. A roller does not necessarily need to form all with said ceramics, and if the slot formation part is formed with said ceramics, it is sufficient for it. The example is as follows.

(1) As shown in drawing 11 (A), form the cylindrical periphery section 81 made from said ceramics with which the wire slot 10 stuck to the metal pipe 80. The stop member 83 for an applied part 82 being formed in the both ends of this metallic pipe 80, and fixing the periphery section 81 to an end is formed.

[0058] (2) As shown in drawing 11 (B), form the cylindrical periphery section 91 made from said ceramics with which the wire slot 10 stuck to the metal pipe 90. The *-like ring part 92 is formed, the reinforcement disk 95 with which the hole 94 opened is formed in a centrum 93, and the lid 96 which fixes this periphery section 91 is fixed to other end 90b by end 90a.

[0059]

[Example 7] Drawing 12 explains the 7th example of this invention. A slot formation part is formed with said ceramics, and this example as well as said 6th example is a case.

(3) As shown in drawing 12 (A), form the cylindrical periphery section 101 made from said ceramics with which the wire slot 10 stuck to the metal pipe 100. The bearing shank 105 is formed in end 2100a of this metal pipe 100, and the truncated-cone-like bearing 106 is formed in other end 100b. The cylindrical crevice 107 is formed in the periphery of this pipe 100, and said cylindrical periphery section 101 is being attached and fixed to this crevice 107.

[0060] (4) As shown in drawing 12 (B), form the cylindrical periphery section 111 made

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from said ceramics with which the wire slot 10 stuck to the metal pipe 110. The truncated-cone-like bearings 115 and 116 are formed in the both ends of this metal pipe 110. The cylindrical crevice 117 is formed in the periphery of this pipe 110, and said cylindrical periphery section 111 is attached and fixed to it by this crevice 117.

[0061]

[Example 8] Drawing 13 explains the 7th example of this invention. In said example, although the slot formation part was formed with said ceramics, this whole multi-slot roller made from the ceramics can also be formed with said ceramics. The example is as follows.

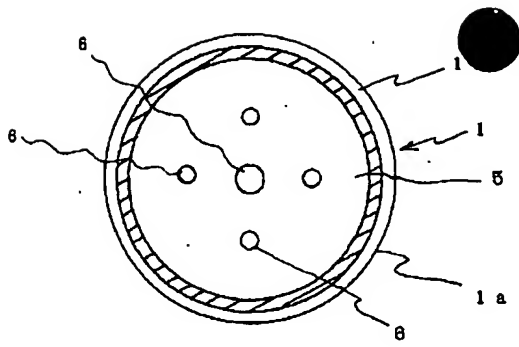
(1) As shown in drawing 13 (A), form the bell shape roller 120 with said ceramics, and form the wire slot 10 in the periphery section 121 of this roller. Since this roller 120 does not have a reinforcement member into a centrum 123 unlike said 1st example, in order to maintain reinforcement, that thickness R_t is thicker than that of the 1st example, for example, is formed in twice as many thickness as this.

[0062] (2) As shown in drawing 13 (B), form the bell shape roller 130 with said ceramics, and form the wire slot 10 in the periphery section 131 of this roller 130. The bearing shank 135 is formed in the end of this roller 130, and the truncated-cone-like bearing 136 is formed in the other end. In addition, the bearing shank 135 is covered with the metal 138, in order to improve concordance with bearing.

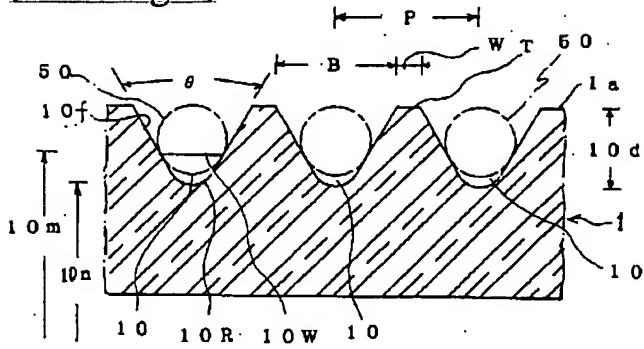
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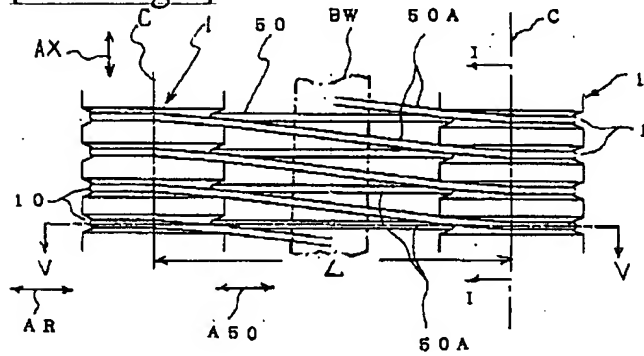
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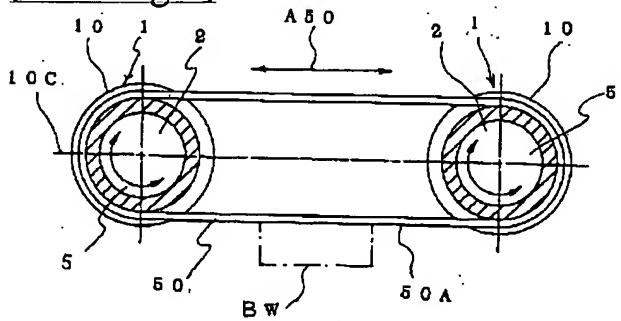
[Drawing 3]



[Drawing 4]

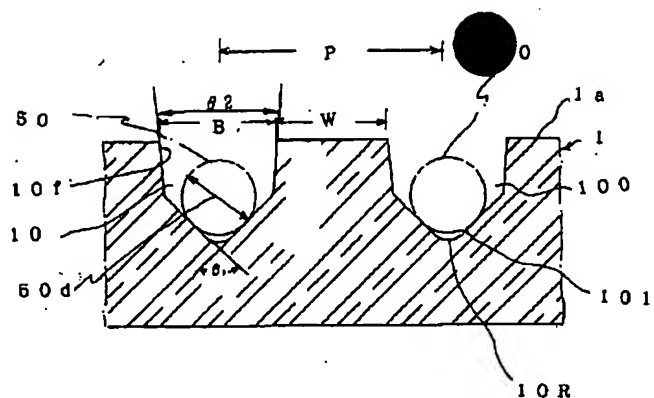


[Drawing 5]

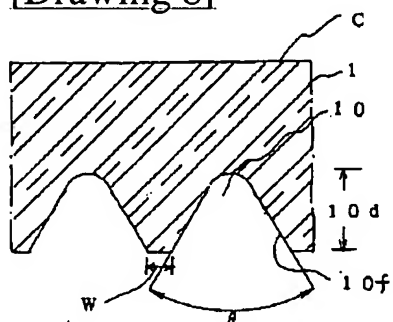


[Drawing 7]

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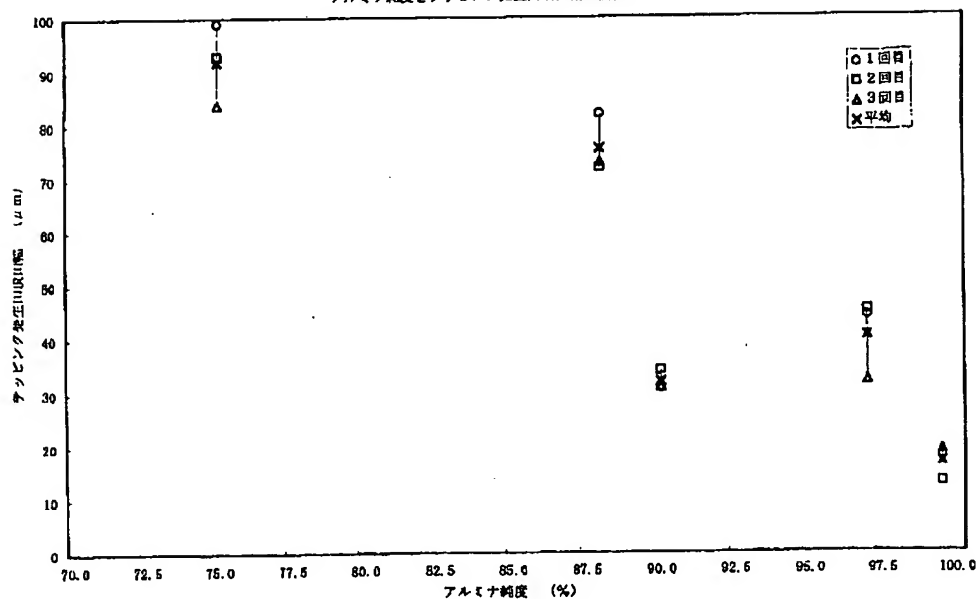


[Drawing 8]



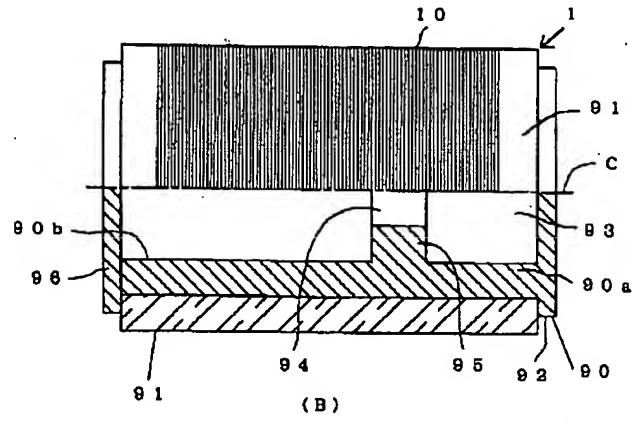
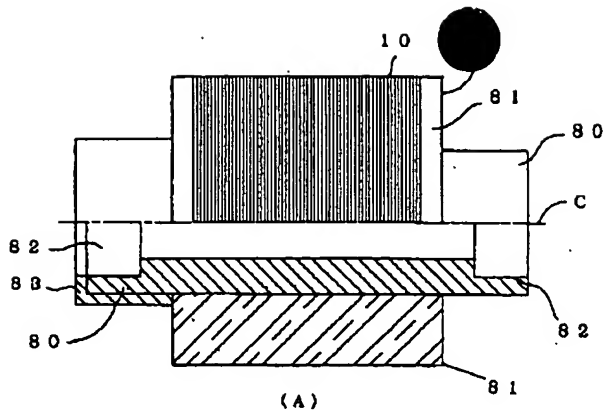
[Drawing 9]

アルミナ純度とチップング発生山頂山幅の関係

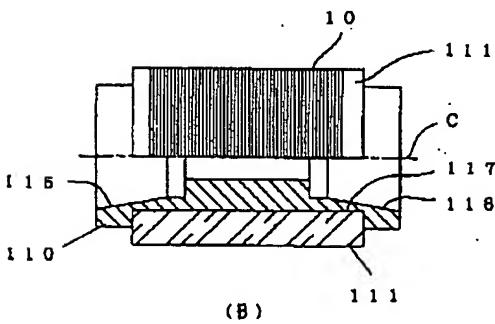
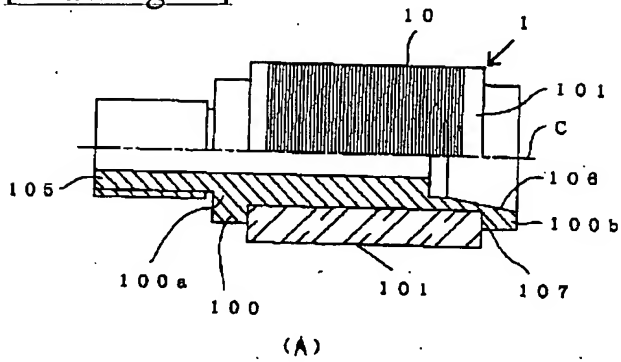


[Drawing 11]

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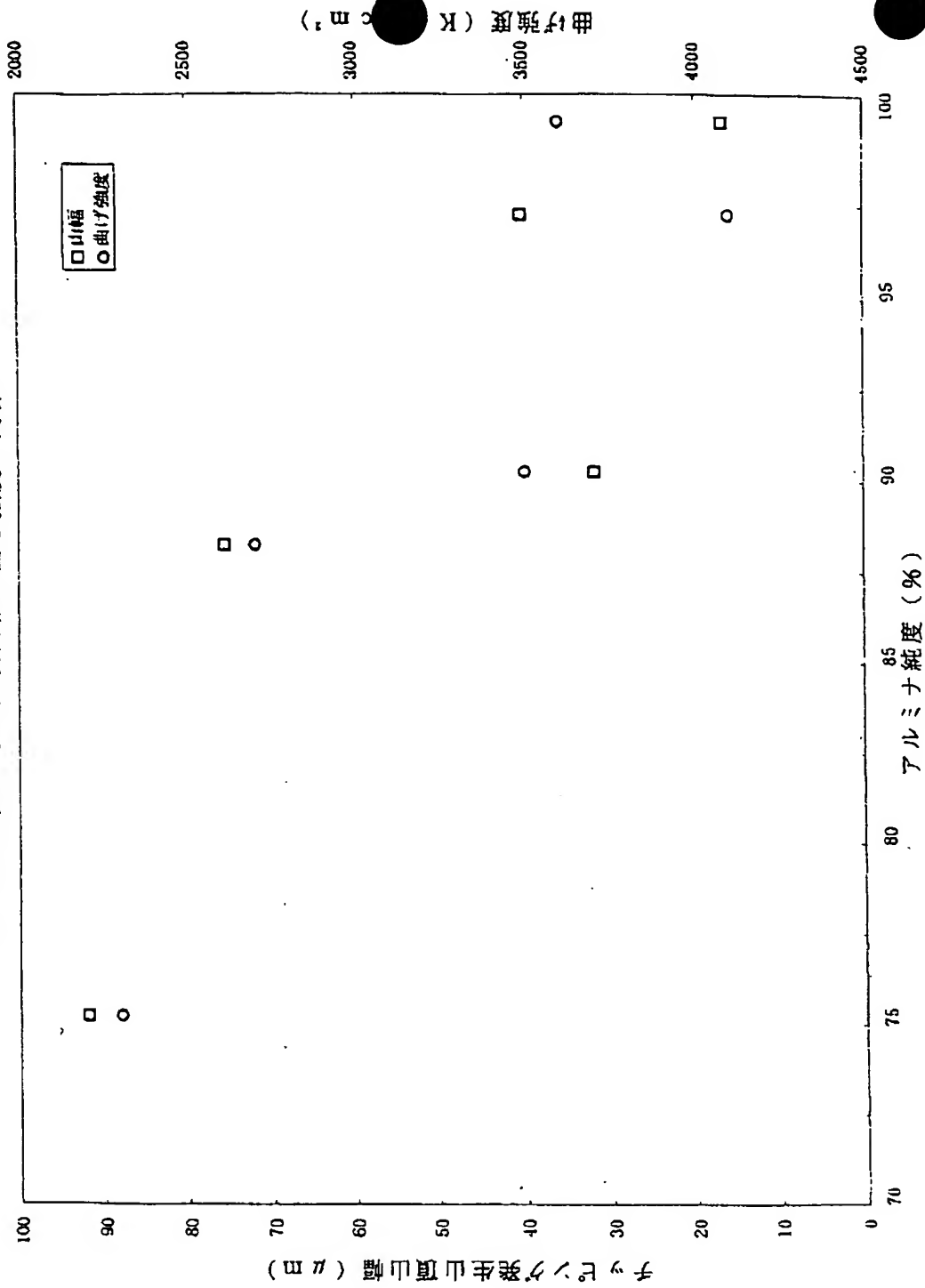
[Drawing 12]



[Drawing 10]

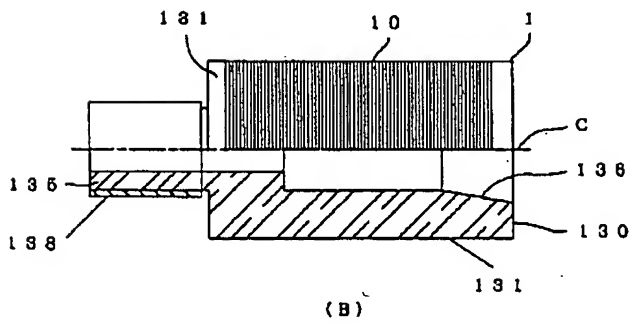
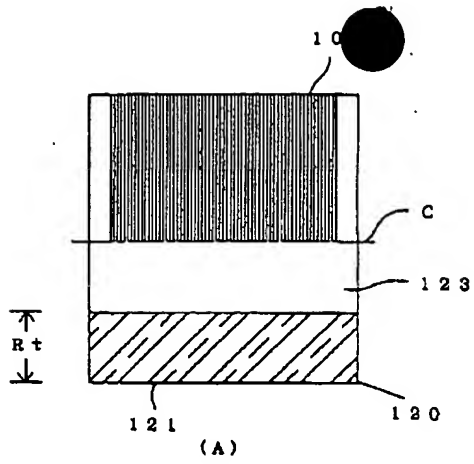
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チップング発生時の山頂山幅と曲げ強度の関係



[Drawing 13]

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